

ECOLOGY AND CONSERVATION OF THE ARUNACHAL MACAQUE *MACACA MUNZALA*



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Nature Conservation Foundation
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ABSTRACT

Biological expeditions in 2003 and 2004 to the biodiversity hotspot of Arunachal Pradesh, Eastern Himalaya resulted in the discovery of the Arunachal macaque *Macaca munzala*, a primate new to science. Belonging to the sinica species-group of the genus *Macaca*, as evidenced by its penile morphology, *M. munzala* differs from the other members of the group, the toque macaque *M. sinica*, bonnet macaque *M. radiata*, Assamese macaque *M. assamensis* and the Tibetan macaque *M. thibetana* in its appearance and morphology, including its relative tail length. We obtained an entire adult male specimen and tissue remains from two other *M. munzala* individuals and conducted detailed morpho-anatomical and molecular genetic studies on them. Although initially hypothesised to be closely related to *M. assamensis* and *M. thibetana* based on similarities in their appearance and distribution, molecular analyses have established the distinct identity of *M. munzala* as an independent species and reveal its phylogenetic affinities with the allopatric *M. radiata* rather than with the geographically closer *M. assamensis* or *M. thibetana*. Morphometric analyses, on the other hand, reiterate its similarity with the two latter species, presumably resulting from convergent evolution under similar ecological conditions.

Our first conservation status assessment for the Arunachal macaque in Tawang and West Kameng districts of Arunachal Pradesh provides a conservative estimate of a total of 569 individuals in 35 troops, largely restricted to altitudes between 2000 and 3500 m. The species seems to be tolerant of anthropogenic habitat change, but is vulnerable to hunting. A low infant to adult female ratio – 17 infants per 100 adult females – suggests that not all adult females reproduce at any given time, and females do not give birth every year. The macaques are persecuted largely in response to crop damage, with the practice of keeping them as pets presumably providing an added incentive to hunting. Data from one part of the surveyed area indicate that the species is able to attain remarkably high population densities in the absence of hunting (estimated at 22.01 individuals

km⁻² in the Zemithang region of Tawang district). Crop damage by the macaque is widespread; patterns in crop damage are similar across altitudinal zones and do not seem to be correlated with macaque density. The species requires immediate protection in human-modified landscapes, while the issues of crop damage and retaliatory persecution need to be addressed urgently.

In order to study the ranging patterns and dietary needs of the Arunachal macaque, and gain better insight into the ecological requirements of the species, two multimale multifemale troops were observed for a period of 112 hours in the Zemithang valley of Tawang district. The two troops, consisting of 22 and 13 individuals respectively, spent, on an average, 48 % of the observed time in moving and foraging, 36 % in sitting and resting, and 16 % in social interactions. Foraging alone accounted for 29 % of the time-activity budget and was the major activity of the macaques throughout the study. The troops had distinct territories with home ranges of 28 ha and 16 ha respectively, much smaller than those of other macaque species studied in similar environments elsewhere. The macaques ranged largely in the secondary scrub habitat in the study area, where they were observed to feed mainly on *Elaeagnus parvifolia* and *Erythrina arborescens*. Although fruits of the former species constituted more than 65.8 % of the overall diet, this largely frugivorous diet could be a seasonal feature. Our preliminary results suggest the ranging and foraging behaviour of the Arunachal macaque to be largely in response to food resource availability and highlight the extensive raiding of agricultural fields and orchards by one of the two study troops. Given the increasing dependence of the species on human-dominated landscapes, it is imperative that awareness programmes for proper human land use and mitigation of human-macaque conflict be initiated in cooperation with the local community and regional government departments for the future welfare of the Arunachal macaque.

1. INTRODUCTION



Biological expeditions in 2003 in the biodiversity hotspot of Arunachal Pradesh, Eastern Himalaya resulted in the discovery of the Arunachal macaque *Macaca munzala*, a primate new to science (Sinha *et al.* 2005; Appendix 4). It was first referred to as the Tawang macaque *Macaca arunachalensis* (Mishra *et al.* 2004). Belonging to the sinica species-group of the genus *Macaca* (Fooden 1980), as evidenced by its penile morphology, *M. munzala* differs from the other members of the group, the toque macaque *M. sinica*, bonnet macaque *M. radiata*, Assamese

macaque *M. assamensis* and the Tibetan macaque *M. thibetana* in its appearance and morphology, including its relative tail length (Sinha *et al.* 2005).

Based on its external morphology, *M. munzala* appears to be closely related to *M. assamensis* and *M. thibetana*; though it differs from both species in certain important traits (Sinha *et al.* 2005). *M. munzala* has so far been reported to largely occur at altitudes between 2000 and 3500 m in much of Tawang district

and parts of West Kameng district, and appears to be restricted to the high altitudes there. This is, in fact, the highest altitude reported for the occurrence of any macaque in the Indian subcontinent (Menon 2003). Looking at the contiguity of the terrain and the habitat where the Arunachal macaque has been recorded, it appears that the species may occur in other parts of Arunachal Pradesh further east, and possibly in the adjoining areas of Bhutan and China as well.

This study, the first on this species, was initiated to collect information on its demography and ecology. We also attempted to understand its interactions with humans as its continued existence may be threatened due to hunting and conflicts with people over crop depredation. In addition to identifying populations and troops for the subsequent establishment of a long-term field study on the species, we aimed to collect basic data on the habitat use, feeding ecology and demography of different populations of the Arunachal macaque in Tawang and West Kameng districts of Arunachal Pradesh. We also aimed to identify potential survival threats to the macaque and conduct an assessment of its conservation status. During the course of the fieldwork, we also came across an entire adult male specimen, and tissue samples from two other individuals. We, therefore, additionally conducted detailed morphometric and genetic analyses of these samples.

The Report

The main body of this report contains three chapters that describe the findings of our study, while some additional information is summarised in the Appendices. In Chapter 2, we present morphometric measurements and compare the morphology and anatomy of *M. munzala* with three other species in the sinica species-group of the genus *Macaca*. The chapter highlights the phylogenetic and morphological affinities of *M. munzala* within the sinica group. In Chapter 3, we present findings of the first assessment of the conservation status of *M. munzala* in western Arunachal Pradesh, the only region from where it is currently reported. We also provide a preliminary assessment of its conflicts with people over crop depredation, and identify the important conservation and research needs for the species. In Chapter 4, we present ecological information obtained from an intensive study of a population of the Arunachal macaque carried out in the Zemithang valley of Tawang district, where we also identified troops for long-term studies on the species. We present information on the activity budget, ranging, and diet of two

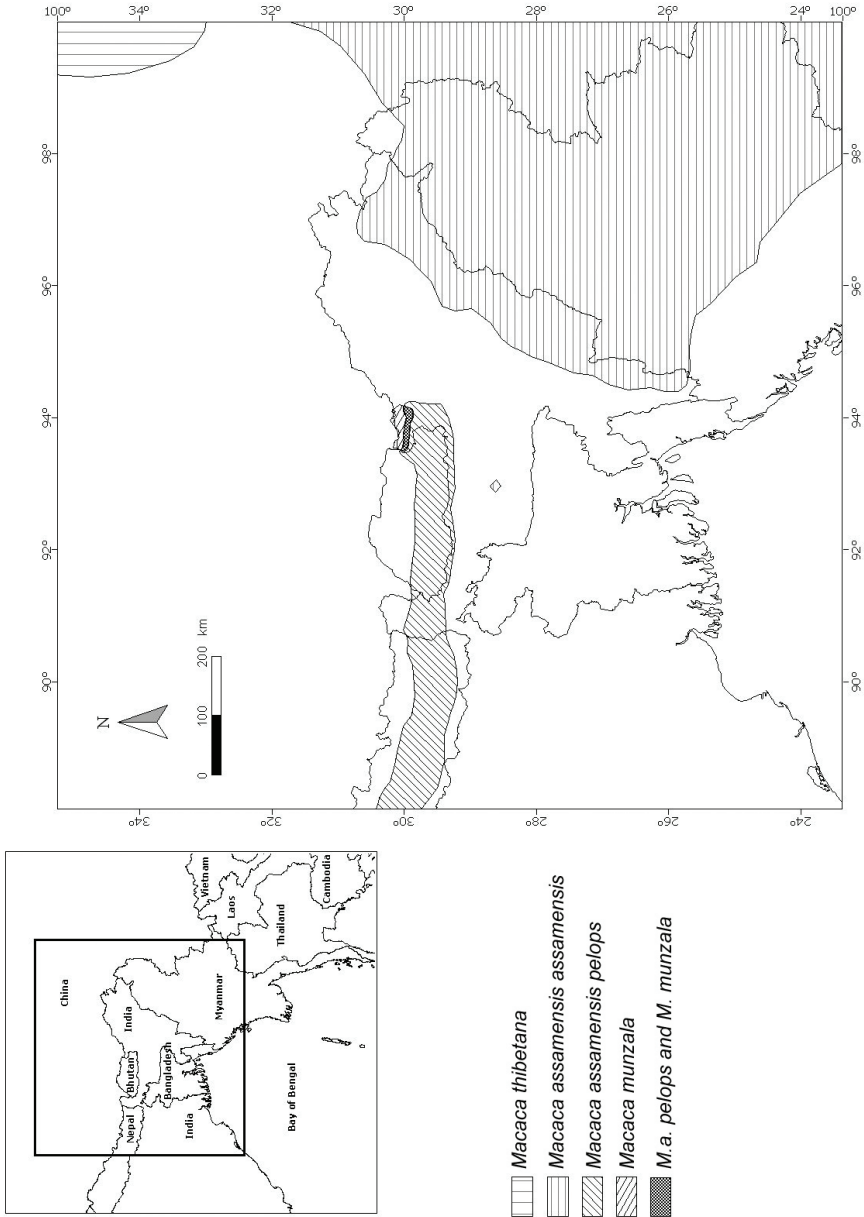


Figure 1. Map showing the known distribution of the Assamese, Arunachal and the Tibetan macaques in northeastern India.

2. MORPHO-ANATOMICAL AFFINITIES AND PHYLOGENETIC RELATIONSHIPS OF THE ARUNACHAL MACAQUE

Anindya Sinha, Jikom Panor and Charudutt Mishra

Abstract

The Arunachal macaque was earlier hypothesised to be closely related to *Macaca assamensis* and *M. thibetana* based on similarities in their appearance and distribution. We subsequently obtained an entire adult male specimen and tissue remains from two other *M. munzala* individuals. Molecular analyses establish the distinct identity of the species, and reveal its phylogenetic affinities with the allopatric *M. radiata* rather than with the geographically closer *M. assamensis* or *M. thibetana*. Morphometric analyses, on the other hand, reiterate its similarity with the two species, presumably resulting from convergent evolution under similar ecological conditions

Introduction

The holotype and paratypes of the Arunachal macaque were originally depicted by photographs, and the distinctive identity of *Macaca munzala* was diagnosed based on a combination of appearance and colouration, relative tail length, and geographical distribution (Sinha *et al.* 2005). The species, a member of the sinica species-group of the genus *Macaca* (classified according to penis morphology), was thought to be closely related to the Tibetan macaque *M. thibetana* and Assamese macaque *M. assamensis* based on their morphological similarities (Sinha *et al.* 2005). On March 7, 2005, we obtained an entire specimen of an adult male *M. munzala* in the Zemithang region of western Arunachal Pradesh, which had entered a house and had been killed by the villagers in self-defense. The specimen was treated at the Itanagar Zoo, tissues collected for molecular analyses, and the skull, baculum, and caudal vertebrae measured and described. The skin, skull, and all retrieved bones and vertebrae were deposited at the State Forest Department, for preservation at the State Forestry Research Institute. During our field surveys, two other tissue samples of *M. munzala* were also obtained from Gyamdong and Lhou, villages close to Zemithang, where the original specimen was found.

In addition to *M. munzala*, *M. assamensis*, and *M. thibetana*, the sinica species-group also includes the bonnet macaque *M. radiata* and the toque

macaque *M. sinica*, which are endemic to peninsular India and Sri Lanka, respectively. To test whether *M. munzala* is indeed closely related to *M. thibetana* and *M. assamensis*, and to determine its phylogenetic position within the sinica group, we have independently conducted molecular analyses of mitochondrial (mtDNA) sequences of *M. munzala* and *M. radiata*, and compared them with available published sequences of *M. thibetana* and *M. assamensis* (Chakraborty *et al.*, in prep.). These analyses have established the distinct identity of the species, and revealed its phylogenetic affinities with the allopatric *M. radiata* rather than with the geographically closer *M. assamensis* or *M. thibetana*. We also compared morphological (body mass, relative tail length) and anatomical (skull, caudal vertebrae, and baculum morphometrics) characteristics of these four species to examine their congruence with the phylogenetic patterns obtained from molecular analyses. Body size and tail length were also examined along a latitudinal gradient to assess the role of ecology in the evolution of this group of primates. In this chapter, we present the results of our morphometric analyses of *M. munzala* and other species within the sinica group.

Methods

To evaluate the morphological and anatomical affinities of *M. munzala*, we conducted detailed morphometric measurements of the adult male specimen by recording 30 craniodental variables of the skull, four measures of the baculum, and the centrum lengths of all caudal vertebrae (see Tables 1 and 2 for the morphometric variables used). These were measured using a slide caliper to a level of accuracy of 0.1 mm. Morphometric measurements for *M. assamensis*, *M. thibetana* and *M. radiata* were obtained from Fooden (1988; skull, baculum and caudal vertebrae) and Pan and Oxnard (2004; skull). In the case of baculum, data were available for adult males of two *M. thibetana*, five *M. radiata*, and four *M. assamensis* individuals. One set of *M. assamensis* baculum data reported in Fooden (1988) was presumably from a subadult with significantly smaller dimensions, and was excluded from the analysis. Skull measurements for the three species other than *M. munzala* were available only as mean values. To assess the similarity in morphometric measurements across species, matrices of Euclidean distances were calculated, and cluster analyses performed separately for skull (mean values) and baculum (individual values). Joining-trees and single-linkage clustering algorithms were used, and the tree plots were standardised to a percent scale by expressing the linkage distance

between any two cases as a percent of the maximum linkage distance.

Table 1. The craniodental and baculum variables used in the morphometric analyses (adapted from Pan and Oxnard 2004 and Fooden 1988, respectively)

Craniodental variables		
No.	Variable	Definition
1.	LBCB	Mandibular bicanine breadth, measured as the maximum distance between the labial (buccal) surfaces of the permanent lower canines at the level of the cemento-enamel junction
2.	LIAW	Mandibular incisor alveolar width, measured between the distal margins of the alveoli of the lateral incisors
3.	CONM1	Distance from the back of the mandibular condyle to the mesial border of the M1
4.	MAM1	Moment arm of the masseter, measured from the top of the mandibular condyle to the ventral border to the angle to mandible (vertical distance)
5.	UI1MDL	Mesiodistal lengths of I1
6.	UCMDL	Mesiodistal lengths of upper canine
7.	UI1BLL	Buccolingual breadth of I1
8.	UI1BLLM	Buccolingual breadth of M1
9.	LI1MDL	Mesiodistal lengths of I1
10.	LI2MDL	Mesiodistal lengths of I2
11.	LCBLL	The greatest width of the lower canine
12.	LM1BLLM	Buccolingual breadth M1
13.	MUZZL	Muzzle length, measured as the distance between orbitale to alveolare
14.	BIORBW	Bioorbital width, measured as the maximum distance between the orbits, between the lateral edges of the orbits at the zygomaticotemporal suture ectoconchion
15.	INTORBW	Interorbital width, measured as the minimum distance between the orbits, between the lateral surfaces of the medial orbital walls at the most superior contacts between the lacrymal and frontal bones (dacryon)
16.	PALWID	Palatal width, measure as the width of the palate between the left and right M1 and M2 teeth (an internal dimension). The tips of the calipers were placed between the M1 and M2 on each side without extending the tips between the teeth
17.	UBCB	Maxillary bicanine breadth, measured as the maximum distance between the labial (buccal) surfaces of the permanent upper canines at the level of the cemento-enamel junctions
18.	UIAW	Maxillary incisor alveolar width, measured as the breadth of the alveoli of the upper incisors, between the lateral margins of the alveoli of the lateral incisors

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19.	PIRH	Height of the piriform (nasal) aperture
20.	CALVL	Cranial length, from glabella to the tip of the occipital protuberance
Craniodental variables		
No.	Variable	Definition
21.	MIDPARW	Midparietal width, measured as the distance between the points on the left and right parietal bones that lie above the external acoustic meatus, at the maximum expansion of the parietals
22.	INFRAMAL	Interfrontomale width, distance between the points on the lateral margins of the frontal processes of the left and right zygomatic bones, at the zygomaticofrontal suture
23.	POSTORB	Postorbital constriction, measured as the minimum width of the postorbital constriction
24.	OCCH	Occipital height, vertical distance from the anterior border of the foramen magnum to the tip of the external occipital protuberance. Distance is measured vertically from the superior edge of a straight edge, which is held at the level of the anterior border of the foramen magnum
25.	FORMAGL	Length of the foramen magnum, from its most posterior point in the midsagittal plane (from basion to opisthion)
26.	FORMAGW	Width of the foramen magnum, measured perpendicular to its length
Baculum variables		
1.	Greatest length	
2.	Least dorsoventral diameter of the shaft	
3.	Shaft length	Measured from proximal extremity of shaft to dorsal inflection point at base of distal process.
4.	Distal process length	Measured from dorsal inflection point at base of distal process to distal extremity

Available data on mean body mass of *M. munzala* and each of the other three species (Fooden 1988) were plotted against the latitudinal mid-points of their known distributions and examined visually for a monotonic positive relationship. We also used the greatest skull length of adult males as a surrogate for body mass, and tested for significant monotonic relationships with latitude, as predicted by the Bergmann's rule (James 1970, Blackburn *et al.* 1999) using Pearson's product-moment correlations. Similar tests were performed to examine whether relative tail lengths showed a significant negative monotonic relationship with latitude as predicted by Allen's rule (Allen 1870, reported in Ray 1960). Differences in the relationship between the linear sequence and size (centrum lengths) of the caudal

vertebrae of the four species were examined graphically. While investigating patterns in body size and relative tail length along latitudinal gradients, we used both community-level (individuals of all species pooled together) and species-level (each species analysed separately) approaches (Brehm and Fiedler 2004). All statistical analyses were performed using Statistica 6 (StatSoft Inc, Tulsa, USA).

Results

Measurements of the baculum and skull of *M. munzala* and of the other three species of the sinica group are presented in Tables 2 and 3. Cluster analysis of the baculum measures reveals a clear pattern separating out a group comprising the three northern species (*M. munzala*, *M. assamensis*, and *M. thibetana*) from the southern *M. radiata* of peninsular India. Within the former group, there is considerable interspersed between *M. thibetana* and *M. assamensis*, while the *M. munzala* stands out as the most distant species within this cluster (Figure 1a). The pattern seen in the cluster analysis of the craniodental measures of the skull is qualitatively similar, but less pronounced (Figure 1b).

Table 2. Craniodental measurements of adult males of the sinica species-group. The craniodental variables have been defined in Fooden 1969, while the measurements for *Macaca assamensis*, *M. thibetana* and *M. radiata* are from Fooden 1988.

Species	Age-sex category	Measure			
		Mean \pm SE, range (n)			
		Greatest Length of Skull (mm)	Relative Zygomatic Breadth	Postrostral Length (mm)	Rostral-postrostral Ratio
<i>M. munzala</i>	Adult males	155.0 (1)	0.68 (1)	107.4 (1)	0.55 (1)
<i>M. assamensis</i>	Adult males	146.9 \pm 1.1, 138.1 - 160.3 (28)	0.66 \pm 0.01, 0.62 - 0.70 (28)	99.4 \pm 0.8, 93.9-107.8 (26)	0.58 \pm 0.01, 0.50 - 0.65 (25)
<i>M. thibetana</i>	Adult males	156.2 \pm 1.4, 146.1 - 167.5 (18)	0.67 \pm 0.01, 0.62 - 0.71 (18)	105.7 \pm 0.8, 102.0 - 112.1 (15)	0.59 \pm 0.01, 0.53 - 0.62 (15)
<i>M. radiata</i>	Adult males	120.0 \pm 4.0, 114.6 - 127.9 (12)	0.67 \pm 0.02, 0.65 - 0.71 (12)	83.1 \pm 2.6, 80.2 - 86.5 (12)	0.54 \pm 0.02, 0.51 - 0.57 (12)

Table 3. Craniodental and baculum measurements of adult males of the *sinica* species-group used in the morphometric analyses. See Table 1 for definitions of the variables. The craniodental measurements for *Macaca assamensis*, *M. thibetana* and *M. radiata* are means for the species (from Pan and Oxnard 2004), while those for the baculum measurements are from individuals (from Fooden 1988). *The *M. assamensis* individual A2 was left out of the final analysis, as it was likely to have been a subadult.

Craniodental variables					
No.	Variable	<i>Macaca munzala</i>	<i>Macaca assamensis</i>	<i>Macaca thibetana</i>	<i>Macaca radiata</i>
1.	LBCB	20.7	24.3	25.1	21.8
2.	LIAW	12.5	14.5	15.1	13.5
3.	CONM1	68.4	69.2	74.0	58.4
4.	MAM1	42.3	44.4	46.8	40.5
5.	UI1MDL	6.0	5.9	6.4	5.5
6.	UCMDL	11.5	10.3	12.1	9.1
7.	UI1BLL	5.5	6.1	6.1	5.7
8.	UI1BLLM	7.5	6.8	7.4	6.4
9.	LI1MDL	4.5	4.2	4.2	4.0
10.	LI2MDL	3.1	4.2	4.2	3.7
11.	LCBLL	6.9	7.5	8.6	7.5
12.	LM1BLLM	6.6	5.6	6.2	5.1
13.	MUZL	58.9	54.4	56.0	45.0
14.	BIORBW	62.9	63.4	60.9	48.1
15.	INTORBW	6.5	7.2	7.5	5.3
16.	PALWID	26.7	27.2	28.2	24.4
17.	UBCB	37.8	36.3	38.3	33.8
18.	UIAW	22.6	21.4	23.2	21.9
19.	PIRH	22.2	23.4	22.8	18.2
20.	CALVL	89.9	94.9	98.5	82.4
21.	MIDPARW	70.6	64.5	65.3	55.6
22.	INFRAMAL	67.8	64.8	70.6	58.8
23.	POSTORB	45.5	49.4	46.3	42.0
24.	OCCH	49.5	22.9	27.6	22.7
25.	FORMAGL	16.4	17.1	17.2	16.7
26.	FORMAGW	14.9	14.1	16.7	14.5

Baculum variables					
1.	Greatest Length	A 30.4	A1 25.2 A2* 17.6 A3 24.2 A4 26.9	A1 24.9 A2 26.3	A1 19.1 A2 18.2 A3 17.5 A4 17.9 A5 19.8
2.	Least dorsoventral diameter of the shaft	A 3.7	A1 3.7 A2* 2.7 A3 3.0 A4 3.6	A1 3.9 A2 4.3	A1 3.0 A2 2.6 A3 2.3 A4 2.9 A5 3.3
3.	Shaft length	A 25.6	A1 22.5 A2* 10.6 A3 21.9 A4 24.9	A1 23.3 A2 21.0	A1 14.9 A2 14.0 A3 14.8 A4 15.0 A5 16.2
4.	Distal process length	A 9.2	A1 6.5 A2* 8.1 A3 6.8 A4 8.1	A1 7.4 A2 9.9	A1 7.5 A2 7.2 A3 5.9 A4 4.7 A5 6.2

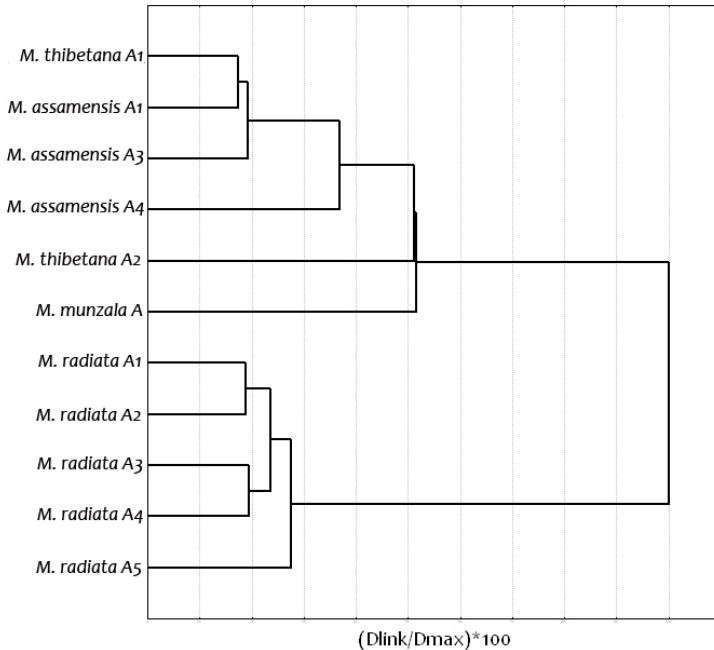


Figure 1(a). Cluster analysis (single-linkage Euclidean distances) of baculum measurements (4 variables) of the *M. munzala* adult male specimen and two adult *M. thibetana*, five *M. radiata*, and three *M. assamensis* males (obtained from Fooden 1988). One *M. assamensis* individual (A2) was removed from the analysis because it could have been a subadult given its significantly smaller dimensions (see Methods).

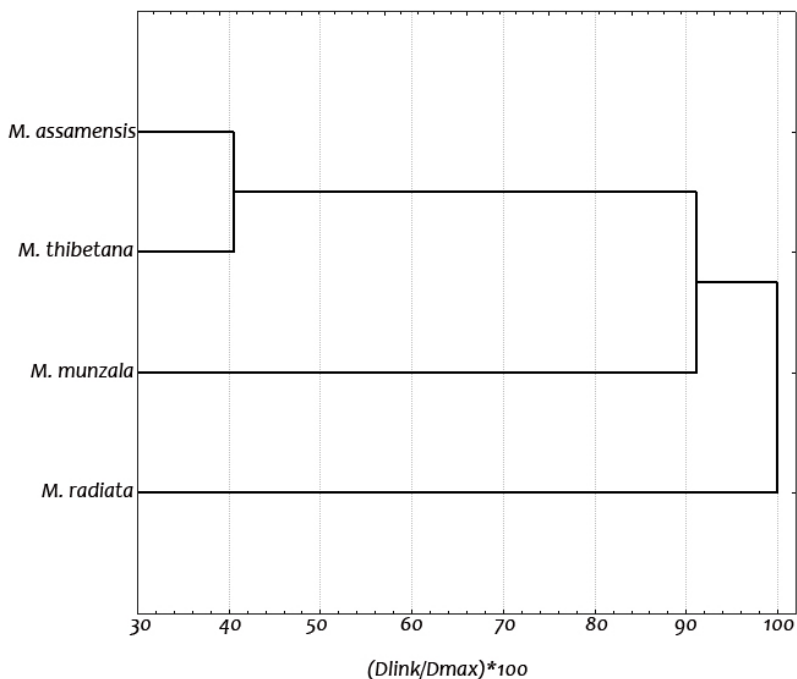


Figure 1 (b). Cluster analysis (single-linkage Euclidean distances) of skull morphometric measurements (26 variables) of the *M. munzala* adult male specimen and mean values of measurements for adult males of *M. assamensis*, *M. thibetana*, and *M. radiata* obtained from Pan and Oxnard 2004. The *M. munzala* specimen had an unusually long OCCH (see Table 2); reanalysis of the data with 25 variables after removing OCCH did not change the clustering pattern qualitatively. However, there was considerable tightening of the upper cluster, with the distance between the two nodes (linking the *M. assamensis*-*M. thibetana* group with *M. munzala*) reducing from c. 50 to c. 5 on a scale of 0-100.

These results contrast significantly with our phylogenetic analyses, which reveal *M. munzala* to be a distinct clade genetically closer to *M. radiata* than to *M. assamensis* or *M. thibetana* (Chakraborty *et al.*, in prep). There is a deep genetic divergence between *M. munzala* and *M. radiata*, both of which nevertheless appear to be of recent origin, while *M. assamensis* and *M. thibetana* form a relatively older paraphyletic clade. It is also noteworthy that while *M. radiata* and *M. thibetana* seem to be the most recently diversified taxa in comparison to the other species in these analyses, *M. munzala* appears to have originated earlier than *M. radiata* and is comparable in its relative divergence time to that of *M. assamensis*.

Amongst the four species examined in our morphometric analyses, the body mass of the relatively northern species appears to be greater than those

occurring at lower latitudes, providing support for Bergman's rule (Figure 2). Furthermore, the community-level analyses of all species including *M. munzala* show a significant increase in greatest skull length (used as a surrogate for body mass) with latitude (Figure 3, Table 4). In the species-level analyses (excluding *M. munzala*), the three species again exhibit significant positive relationships between greatest skull length and latitude as predicted by the Bergmann's rule (Table 4). There is also a significant negative correlation between relative tail length and latitude in the community-level analysis, thus providing support for Allen's rule (Table 4). However, in the species-level analysis, the relationship is significantly negative only for *M. assamensis*, but not for *M. thibetana* or *M. radiata* (Table 4). Analysis of the structure and linear arrangement of the caudal vertebrae nevertheless showed that both their numbers as well as their lengths seem to reduce with increasing latitude. *M. munzala*, however, is an exception, which, although fitting the pattern well in terms of the total number of vertebrae (intermediate between the immediately northern *M. thibetana* and southern *M. assamensis*), has relatively longer vertebrae (Figure 4).

Table 4. Relationship between morphological attributes and latitudinal distribution among macaque species of the *sinica* species-group, showing Pearson's correlation coefficients between (i) greatest skull length and latitude, and (ii) relative tail length (ratio of tail length to head and body length) and latitude for adult males. Significant monotonic and positive relationships in (i) would indicate agreement with Bergmann's rule, while significant monotonic and negative relationships in (ii) would indicate agreement with Allen's rule. Sample sizes are indicated in parentheses. The overall correlation in the top row represents a community-level analysis for all species combined including *M. munzala*, for which sample sizes were limited. The subsequent rows represent species-level analyses (see Methods).

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Species	Greatest skull length	Relative tail length
All species	0.878 (59) ***	-0.849 (38) ***
<i>Macaca assamensis</i>	0.485 (28) **	-0.646 (16) **
<i>Macaca thibetana</i>	0.534 (18) *	-0.177 (08)
<i>Macaca radiata</i>	0.632 (12) **	0.520 (12)

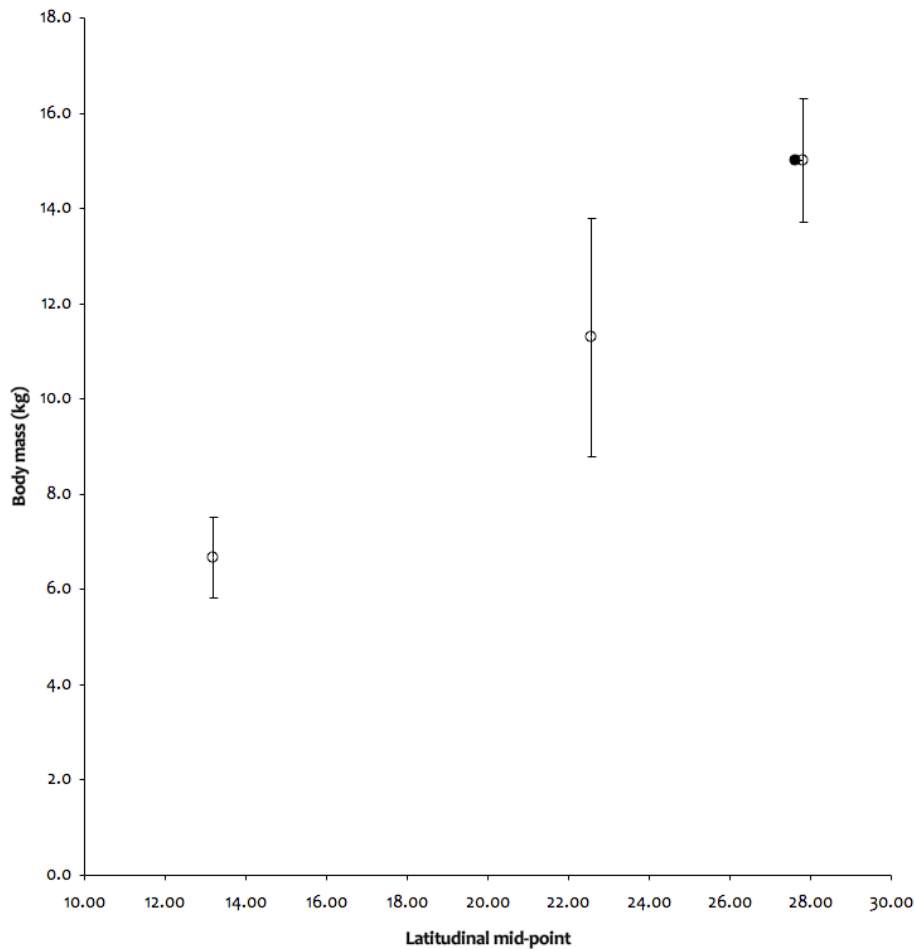


Figure 2. Mean body mass (\pm SD) of adult male macaques of the sinica species-group (left to right: *Macaca radiata*, *M. assamensis*, *M. munzala*, and *M. thibetana*) plotted against the latitudinal centre points of the known species distributions. The closed circle represents the single available body mass for *M. munzala*.

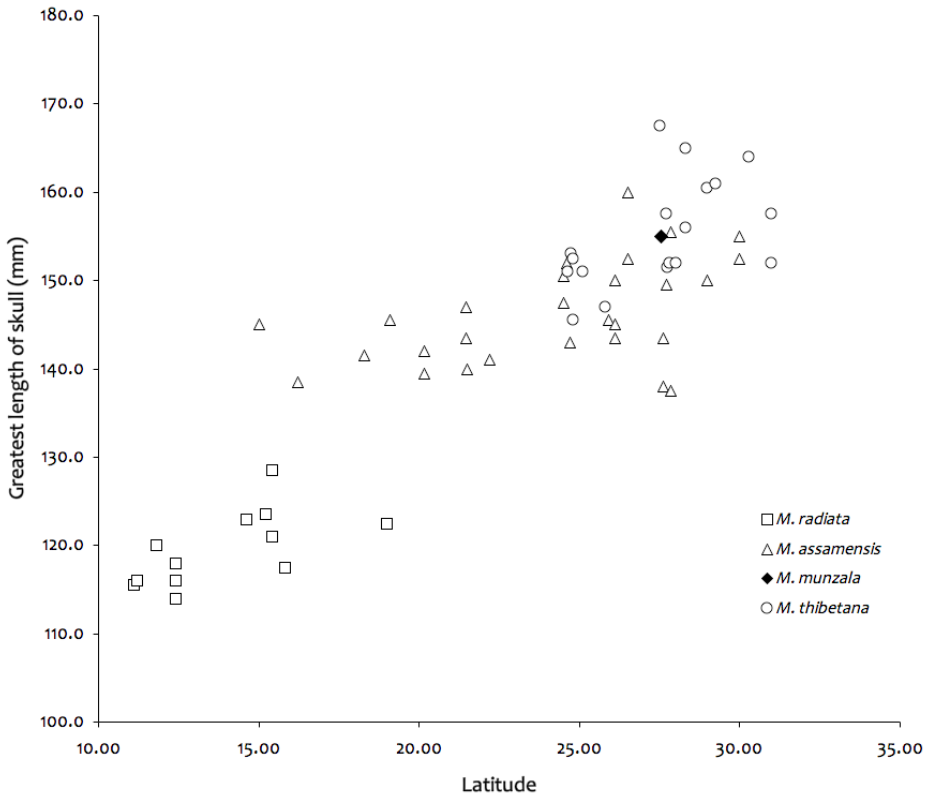


Figure 3. Greatest skull length of adult male individuals of the sinica species-group (*Macaca radiata*, *M. assamensis*, *M. munzala*, and *M. thibetana*) plotted against latitude. The closed diamond represents the single available greatest skull length for *M. munzala*.

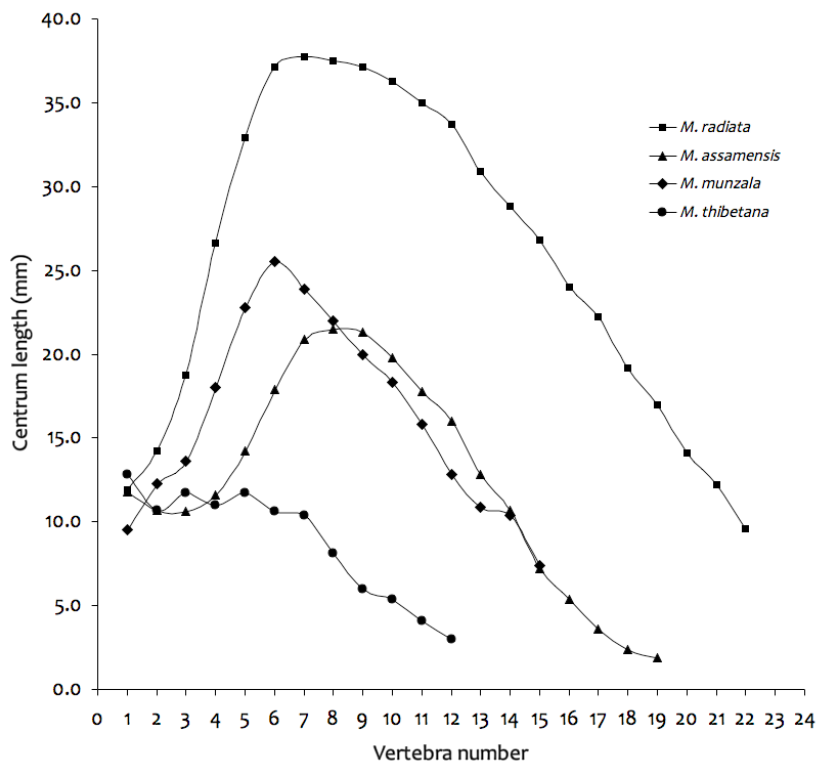


Figure 4. Centrum lengths of the caudal vertebrae of the adult male *M. munzala* specimen (closed triangles) compared with the mean centrum lengths (from Fooden 1988) of the three other species of the *sinica* species-group, plotted against vertebra number. The species from top to bottom in the legend are ordered according to increasing latitudinal mid-points of their distribution (see Figure 3).

Discussion

M. munzala has recently been identified as a distinct species within the *sinica* species-group of the genus *Macaca* based on its unique morphology and geographical distribution (Sinha *et al.* 2005). Molecular genetic analyses have also confirmed this finding by placing it as a distinct, coherent clade, separate from the *M. radiata* and *M. assamensis*-*M. thibetana* clades, within the *sinica* species-group (Chakraborty *et al.*, in prep.).

Based on similarities in morphological characteristics and ecological distribution (in the Eastern Himalaya and adjoining areas of south China and southeast Asia) between *M. munzala*, *M. assamensis*, and *M. thibetana*, Sinha *et al.* (2005) had suggested the possibility of close phylogenetic relationships between

these species. Surprisingly, however, our molecular analyses established a much closer relationship of *M. munzala* with the geographically and ecologically more distant *M. radiata* of tropical peninsular India (Chakraborty *et al.*, in prep.).

Morpho-anatomical analyses of the *M. munzala* adult male specimen and its comparison with the other three species nevertheless reveal close affinities between this species and the *M. assamensis*-*M. thibetana* clade. Although structurally distinct, both the baculum and the skull of *M. munzala* bear greater similarity with those of *M. assamensis* and *M. thibetana* and cluster with them rather than with *M. radiata*. This apparent morphological convergence of *M. munzala* with the *M. assamensis*-*M. thibetana* clade, despite their relatively high genetic divergence, could be explained by similarities in their ecological environments. These three species have been reported from subtropical and temperate regions (with *M. assamensis* also occurring in some tropical forests), while *M. radiata* is largely confined to the warm tropical areas of peninsular India.

More specific morphological patterns within and between closely related species along temperature/latitudinal gradients have been hypothesised by Bergmann's and Allen's rules (see Meiri and Dayan 2003 for a review of Bergmann's rule). Our analysis reveals a clear latitudinal increase in body mass and greatest skull length within the *sinica* species-group of macaques, both at the community- and the species-level, as predicted by the Bergmann's rule (see Fooden 1988 for a similar species-level regression analysis). Furthermore, although a decline in relative tail lengths of these species along a latitudinal gradient, as predicted by Allen's rule, was less pronounced (but see Fooden 1988), analysis of their caudal vertebral structure and organisation clearly suggested a simultaneous decrease in both the number and size of these vertebrae with increasing latitude. The *M. munzala* vertebrae, while fitting well with the general pattern of reduction in vertebrae number, however, appear to stand out in their relatively large size. These patterns nevertheless point to the important role that ecology may have played in bringing about the adaptive morphological and anatomical convergence of *M. munzala* with the northern species of this group, despite its phylogenetic closeness to *M. radiata*.

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3. DISTRIBUTION AND CONSERVATION STATUS OF THE ARUNACHAL MACAQUE

R Suresh Kumar, Nabam Gama, R Raghunath, Anindya Sinha and Charudutt Mishra

Abstract

The Arunachal macaque *Macaca munzala* has so far only been reported from western Arunachal Pradesh, Eastern Himalaya. We report the results of the first conservation status assessment for the species. Our surveys enumerated a total of 569 individuals, which is a conservative estimate of the macaque population in Tawang and West Kameng districts of Arunachal Pradesh. The species seems to be tolerant of anthropogenic habitat change, but is vulnerable to hunting. A low infant to adult female ratio (17 infants per 100 adult females) suggests that not all adult females reproduce at any given time, and females do not give birth every year. The macaques are persecuted largely in response to crop damage, with the practice of keeping them as pets presumably providing an added incentive to hunting. Data from one part of the surveyed area indicate that the species is able to attain remarkably high population densities in the absence of hunting (estimated at 22.01 individuals km⁻² in the Zemithang region of Tawang district). Crop damage by the macaque is widespread; patterns in crop damage are similar across altitudinal zones and do not seem to be correlated with macaque density. The species will need to be protected in human-modified landscapes, and the issues of crop damage and retaliatory persecution must be addressed urgently.

Introduction

Conservation of primates is a global challenge today. A quarter of all recognized taxa (> 625 species and subspecies) of primates are listed either as Critically Endangered or Endangered in the IUCN's Red List of Threatened Species (Mittermeier *et al.* 2005). The conservation status of nearly 50 % of primate species worldwide (c. 250 species) is currently a matter of serious concern (Chapman and Peres 2001), with hunting and degradation of their forest habitat being the two most important proximate threats to primates worldwide (Hill 2002, Mittermeier *et al.* 2005).

The northeastern part of India (c. 255,000 km²), comprising seven states, supports the highest diversity (11 species) of primates in the country (Choudhury

2001, Srivastava and Mohnot 2001, Kumar *et al.* 2005, Sinha *et al.* 2005). Amongst these states, Arunachal Pradesh (26°28'–29°30'N and 91°30'–97°30'E; 83,743 km²; Figure 1) is arguably the country's richest region in terms of its terrestrial biodiversity. A wide altitudinal range (100 to >6000 m), an associated diversity of habitats (tropical rainforests, sub-tropical and temperate forests, alpine meadows) and a unique location at the junction of the Eastern Himalaya and Indo-Burma biogeographical zones have contributed to the rich diversity of mammalian fauna in this state (Mishra *et al.* 2004). Large forest tracts still remain in Arunachal Pradesh, in part due to its low human population density (13 km²).

Recent surveys in the mid- to high elevations of western Arunachal Pradesh led to the discovery of a rich assemblage of mammals (Mishra *et al.* 2006), including the Arunachal macaque *Macaca munzala* (Sinha *et al.* 2005). Belonging to the sinica species-group of the genus *Macaca*, this primate occurs largely at altitudes between 2000 to 3000 m in Arunachal Pradesh's westernmost district of Tawang (2172 km²; Figure 1). Its occurrence, albeit relatively more rare, was also confirmed in the adjoining West Kameng district (7422 km²) of the state. Given the contiguity of habitat, the Arunachal macaque should also occur in the bordering areas of central Arunachal Pradesh, as well as in parts of Tibet and Bhutan, though these areas remain to be surveyed for the species.

Within Arunachal Pradesh, we believe that the Tawang district, given its particular ethnic composition and practices, should support the highest density of the Arunachal macaque and provide for its best conservation prospects. In most other areas of the state, hunting, an important part of the tradition for most of Arunachal Pradesh's 26 tribes, seriously threatens most wildlife populations (Datta 2006). Today, it is no longer sustainable, and is believed to be leading to 'empty forests', a state where the vegetation may appear intact but many of the large animal populations are either extinct or heavily depleted (Redford 1992, Datta 2006). Primates are commonly hunted throughout Arunachal Pradesh, with most of the tribes using them for meat and medicine (Borang and Thapliyal 1993, Singh 2001, Solanki and Chutia 2004). However, people of the Monpa agro-pastoral tribe inhabiting the Tawang district and constituting c. 5 % of the population of the state, generally do not hunt primates for meat (Solanki and Chutia 2004, Mishra *et al.* 2006). Furthermore, due to their Buddhist beliefs, hunting, though prevalent, is not as widespread or culturally ingrained in the Monpa community as it is in most other tribes of Arunachal Pradesh. In fact, some of the villages in Tawang

have voluntarily prohibited the hunting of wildlife in their village forests (Mishra *et al.* 2006). During our earlier surveys, many of our sightings of the Arunachal macaque were in the proximity of villages, and though wary of people, we found the macaques to be relatively tolerant of human presence (Sinha *et al.* 2005). This is in stark contrast to most other areas of Arunachal Pradesh, including the adjoining West Kameng district, where primates are less frequently sighted, and are extremely shy of human presence (Mishra and Sinha, pers. obs.).

We, nevertheless, did record a certain level of persecution of the Arunachal macaque from even within the Tawang district, largely in retaliation against crop damage (Sinha *et al.* 2005, Mishra *et al.* 2006). Macaque flesh is also considered to be of medicinal value locally, particularly for livestock (Mishra and Sinha, pers. obs.; see also Solanki and Chutia 2004). We also observed the practice of capturing and keeping juvenile macaques as pets amongst many Monpa people (Sinha *et al.* 2005). Against this background, what are the conservation prospects for the Arunachal macaque?

In this chapter, we report an assessment of the conservation status of the Arunachal macaque in western Arunachal Pradesh, the only region where the species is so far reported to occur. Our focal area was the Tawang district, which presumably is a relatively high macaque-density region, although we also present some observations from West Kameng. Our first objective was to map the current distribution of the Arunachal macaque and generate a preliminary estimate of their abundance through extensive field surveys in western Arunachal Pradesh. Our second objective was to develop an understanding of the nature and extent of conflict between the Arunachal macaque and the local people through extensive village-level surveys and interviews.

Study area

The Tawang and West Kameng districts of Arunachal Pradesh, where this study was carried out, together encompass a wide altitudinal gradient extending from c. 150 m to c. 7000 m, with the Great Himalayan Range forming the northern boundary. The region is drained by the Tawang Chu, Nyamjang Chu and their tributaries in Tawang, and the Bhareli and its tributaries in West Kameng. The main vegetation types include broadleaved forests (up to 3000 m, with species such as the *Rhododendron*, *Acer*, *Alnus*, and *Quercus* as the dominant species), conifer-broadleaved forests (3000-4200 m, *Abies densa*, *Juniperus*, *Larix*, *Picea*, *Rhododendron*, *Quercus*),

Rhododendron scrubland (krummholz vegetation at 4000-4300 m, near the tree-line), dwarf *Rhododendron* meadows (meadows between 4200-4600 m rich in graminoids and forbs such as *Fagopyrum*, *Juncus*, *Aster*, *Anemone*, and with a short mat of *Rhododendron*), high altitude grassy meadows (alpine meadows between 4350-5250, with species such as *Stipa*, *Saxifraga*, *Leontopodium*, and *Artemisia*) and forest clearings (pastureland created by clearing and burning broadleaved forests and conifer-broadleaved forests with shrubs such as *Rosa* and *Berberis*, and forbs such as *Anaphalis*, *Potentilla*, *Sambucus*, *Rumex*, and *Senecio*). At low- to mid-elevations, the broad-leaved forests are considerably degraded in the vicinity of human habitations and appear as secondary scrub, with reduced tree cover and dominated by species such as *Erythrina*, *Rhus*, *Elaeagnus*, and *Debregeasia* (Mishra *et al.* 2004).

The other primates in the region include the capped langur *Trachypithecus pileatus*, Assamese macaque *Macaca assamensis*, rhesus macaque *M. mulatta*, and the slow loris *Nycticebus bengalensis*. Amongst macaques, the Arunachal macaque was the predominant species in the altitudinal range that we surveyed. In fact, we did not sight any other macaque in the Tawang region during the surveys, although some of the troops of the Arunachal macaques at lower altitudes appeared to have morphologically variant individuals, which could also represent hybrid individuals of the Arunachal and Assamese macaques (Sinha and Mishra, in prep.). The region's wildlife includes, in addition, mountain ungulates such as the serow *Nemorhaedus sumatraensis*, three species of goral *Nemorhaedus spp.*, takin *Budorcas taxicolor*, and carnivores such as the dhole *Cuon alpinus*, Himalayan black bear *Selenarctos thibetanus*, and the snow leopard *Uncia uncia* in the higher altitudes.

The people in the two surveyed districts are largely agro-pastoralists, with a few villages in the high altitude areas being predominantly pastoral. Millet and maize are the two major crops grown in the area, followed by wheat, buckwheat, potatoes and chillies. Vegetable crops and fruits like apple, peach and plum are also grown in kitchen gardens and near settlements. Cultivation can be found up to 3000 m. People in Tawang and in the surveyed parts of West Kameng district mainly practice settled agriculture unlike in most other districts of the State where shifting cultivation is predominant.

While the Monpa tribe is the predominant community inhabiting the Tawang district, the adjoining areas of West Kameng also have Sherdukpen, Khowa, Aka, and Miji communities, in addition to the Monpa. Tawang has a higher human

density of 16 per km², while West Kameng has a lower human density of 10 per km² (Government of India 2005).

Methods

Distribution and density of the Arunachal macaque

This study was conducted between April 2004 and August 2005. We conducted extensive vehicular surveys to locate macaque troops, covering a distance of c. 1000 km three times. Along these survey routes we stopped to scan for macaques at selected vantage points regularly. Surveys were also made on foot covering nearly 400 km along existing trails and paths in the area. At every sighting, information on the troop size and composition was recorded along with information on altitude, GPS location and broad habitat features. These data gave an estimate of the minimum population of the Arunachal macaque, and were transferred on a map to depict the distribution of the macaque in Western Arunachal Pradesh. In cases where macaque troops were sighted in the same area again, and where there was a possibility of double counts, we have used data only from the sighting where we recorded the maximum number of individuals. Furthermore, in most instances (86%), we could not enumerate all the individuals in a troop due to the intervening vegetation. The data, therefore, represent partial counts and provide, at best, a conservative estimate of the population.

The Zemithang region of Tawang district is the area with the least hunting pressure in the survey sites as most of the village councils here have voluntarily prohibited hunting (Mishra *et al.* 2004). This is in fact the region from where the holotype and paratypes of the Arunachal macaque was first reported (Sinha *et al.* 2005). Within Tawang district, Zemithang also appeared to be an area of relatively high macaque density. To estimate the density of the Arunachal macaque in this area, we extensively surveyed, located, and enumerated most of the troops occurring here in a 10.6 km² area.

Human-macaque relationships

Our study on the conflicts between people and the Arunachal macaque was based on interviews with local people in the Tawang and West Kameng districts. To get a preliminary idea of the nature and distribution of conflicts, we initially conducted rapid assessments in villages across the study site (54 and 10 in Tawang and West Kameng, respectively). In each village, at least one to six individuals or groups

of individuals were interviewed. Without invoking the macaques, we asked the interviewees to list the factors they believed were responsible for crop losses in the area. The potential factors considered were frost, disease, insect pests, rodents or wildlife. The interviewees' perceptions of the importance of each factor were graded as 'very serious', 'serious', 'moderate', 'low' or of 'no concern'. The interviewees were then asked specifically about the wildlife species causing crop losses and their responses were graded in a similar fashion. For simplicity, during analysis, the two highest categories (very serious and serious) of the intensity of conflict were combined into a single one called 'high'. The wildlife categories in this survey included wild pig, deer, birds, macaques, porcupines, and rodents. Data on altitude, GPS location and crops grown in each of the villages visited were also recorded.

From the 64 villages originally surveyed, we selected six villages for collecting further information on conflicts by conducting door-to-door interviews. Four of these villages, Rho, Shyro, Jangda and Thingbu were located in Tawang, while Morshing and Berchii were located in West Kameng. Five of the surveyed villages were large, while Berchii in West Kameng was small with only 13 families. In all these villages we interviewed at least one member in each family. We asked each interviewee about the extent of crop losses due to macaques, graded their response, and estimated the extent of conflict by examining the proportion of respondents in each category ('low', 'medium', 'high'). The interviewees were also asked about which crops were damaged, how often macaques raided the crop fields, seasonality of crop damage and the extent of crop loss in monetary terms. Further, each of the interviewees was asked whether and how many macaques they had killed, what techniques they had employed, and what they had done with the carcasses, if any.

Results

Distribution and abundance of the Arunachal macaque

We sighted a total of 35 distinct troops and at least 569 different individuals of the Arunachal macaque during our surveys (Table 1; see Appendix 1 for a complete listing of all troops). Of these, 32 troops (540 individuals) were sighted in Tawang, and 3 (29 individuals) in West Kameng (Figure 2). Information from local people indicated the possible occurrence of at least 25 other troops in the region. Most of the macaques were sighted within the 2000-2250 m altitudinal zone, though

we recorded them up to 3000 m in fir *Abies densa* forests (Figure 1). Local people reported seasonal occurrence of macaques up to 3500 m, and we accordingly estimated the total potential macaque habitat (all areas below 3500 m) within Tawang district to be c. 800 km² (approximately one third of the district's total area). In the Zemithang area, which has relatively high macaque abundance and where we enumerated most of the existing troops, we recorded 10 troops (234

Table 1. Distribution of Arunachal macaque *Macaca munzala* troops and individuals by vegetation type.

Vegetation type	Number of troops	Number of individuals	Percentage of total individuals sighted
Crop fields	4	34	6.0
Degraded broadleaved forest	9	165	29.0
Degraded open scrub	7	154	27.1
Forest clearing	3	87	15.3
Abies forest	3	23	4.0
Dense oak forest	7	63	11.1
Riverine forest	2	43	7.6
TOTAL	35	569	

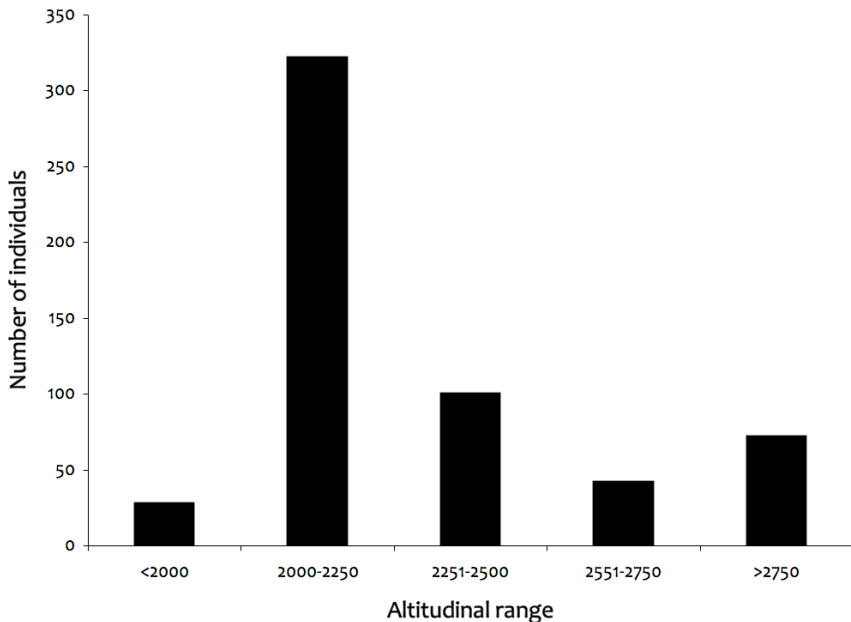


Figure 1. Altitudinal distribution of the sightings of the Arunachal macaque *Macaca munzala* in Tawang and West Kameng districts of western Arunachal Pradesh.

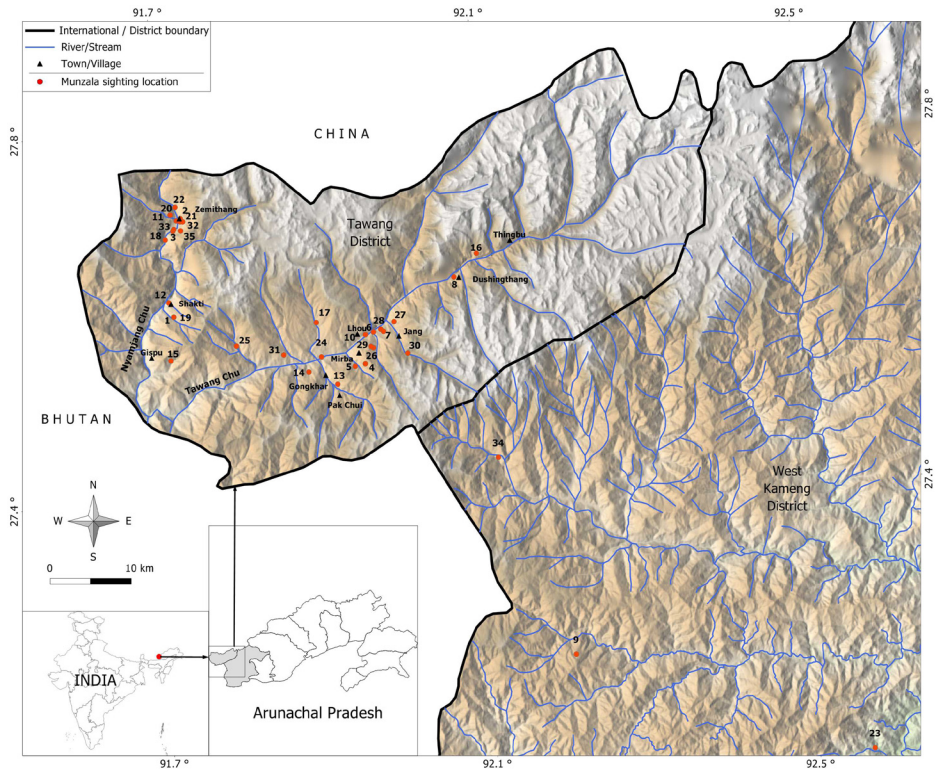


Figure 2. Map showing the sighting locations of the Arunachal macaque *Macaca munzala* in western Arunachal Pradesh, Eastern Himalaya. The cluster of sightings in northwest Tawang district represents those from the high-density Zethang area where hunting is prohibited by the village councils.

individuals), and estimated a density of 0.94 troops and 22.01 individuals km^{-2} .

Over three-fourths of the individuals of the Arunachal macaque sighted during our surveys were in human-modified landscapes and forests (Table 1). Over half of the individuals sighted were in degraded broadleaved forests and degraded open scrub in the vicinity of human habitation. These degraded forests have moderate to high levels of anthropogenic disturbance in the form of felling, livestock grazing, lopping, and leaf litter collection.

The troop size of the Arunachal macaque ranged from solitary to > 60 individuals. Troops were generally multimale multifemale, with an average (\pm SD) size of 16.3 ± 13.4 individuals. In the troops where a majority of individuals could be classified ($n = 22$), the overall adult sex ratio was 52 males per 100 females,

while the infant to adult female ratio was 17 per 100 females, and the juvenile to adult female ratio 110 per 100 females. Our preliminary demographic data on six troops observed in some detail during the period from August 2003 to May 2006 suggests that the adult females in these troops may have an interbirth interval of two years, but longer-term observations are required to confirm this finding.

Human-macaque relationships

In 69 % of the villages where perception surveys were conducted ($n = 64$ villages), people reported wildlife to be the most common cause of high crop losses (Figure 3a). Crop diseases, insect pests, and rodents were reported to cause high crop losses in only two, one, and two of the surveyed villages, respectively. Amongst

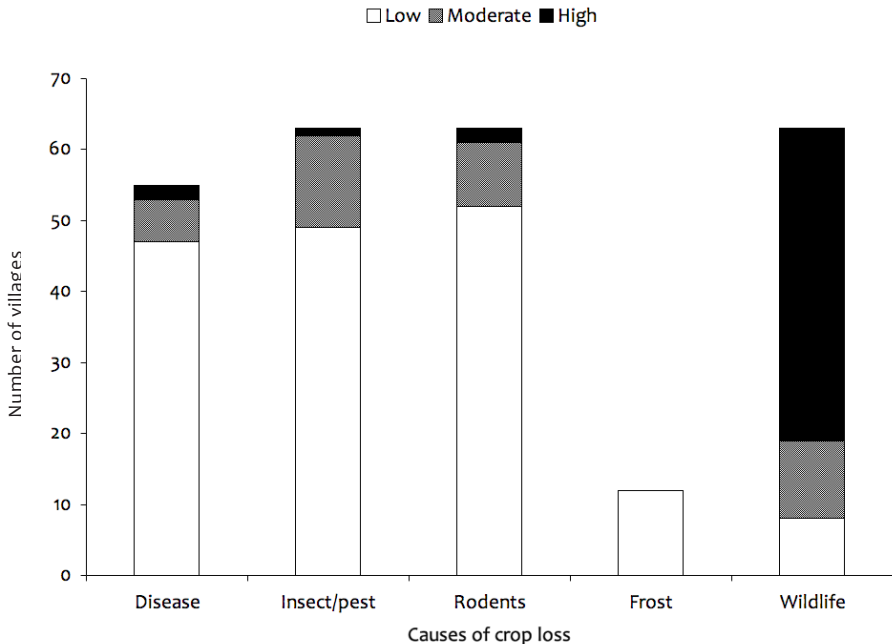


Figure 3a. The main causes of crop losses identified by the local people during perception surveys of human-primate conflict in western Arunachal Pradesh. The stacked bars represent the number of villages where each factor was identified to be a cause of crop loss (out of 64 total villages surveyed). This figure shows the extent of crop losses reported due to various factors including disease, climate, and wildlife.

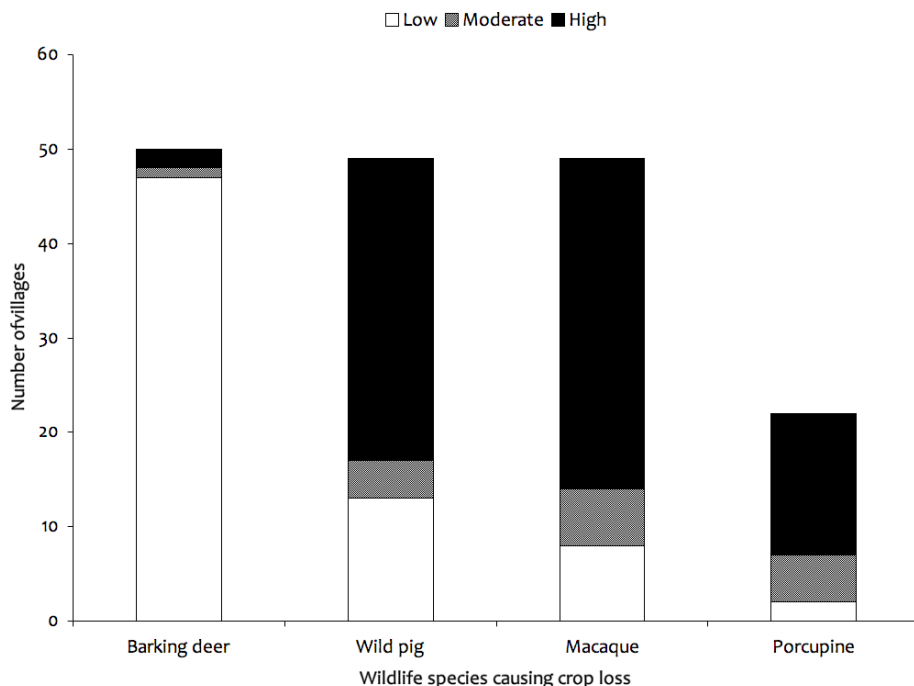


Figure 3b. The main causes of crop losses identified by the local people during perception surveys of human-primate conflict in western Arunachal Pradesh. The stacked bars represent the number of villages where each factor was identified to be a cause of crop loss (out of 64 total villages surveyed). This figure shows the extent of crop losses attributed to various wildlife species. .

wildlife, macaques and wild pigs were the dominant species reported to cause high losses (55 % and 50 % of the surveyed villages, respectively), while porcupines were reported to cause significant losses in 23 % of the surveyed villages (Figure 3b). Other wildlife species reportedly causing some amount of crop losses in the area were the Himalayan black bear, goral, and birds such as the kaleej pheasant *Lophura leucomelana* and black birds *Turdus spp.*

The extent of crop damage by macaques is presumably the highest in the altitudes between 2000-2500 m owing to the greater abundance of villages and agricultural fields in this zone (Figure 4). Patterns in the intensity of crop damage, however, seemed similar across altitudinal zones (Figure 4). The only exception was the high-altitude zone where both the extent of agriculture as well as the density of macaques is limited.

In the detailed door-to-door surveys in six villages, 3 % out of a total

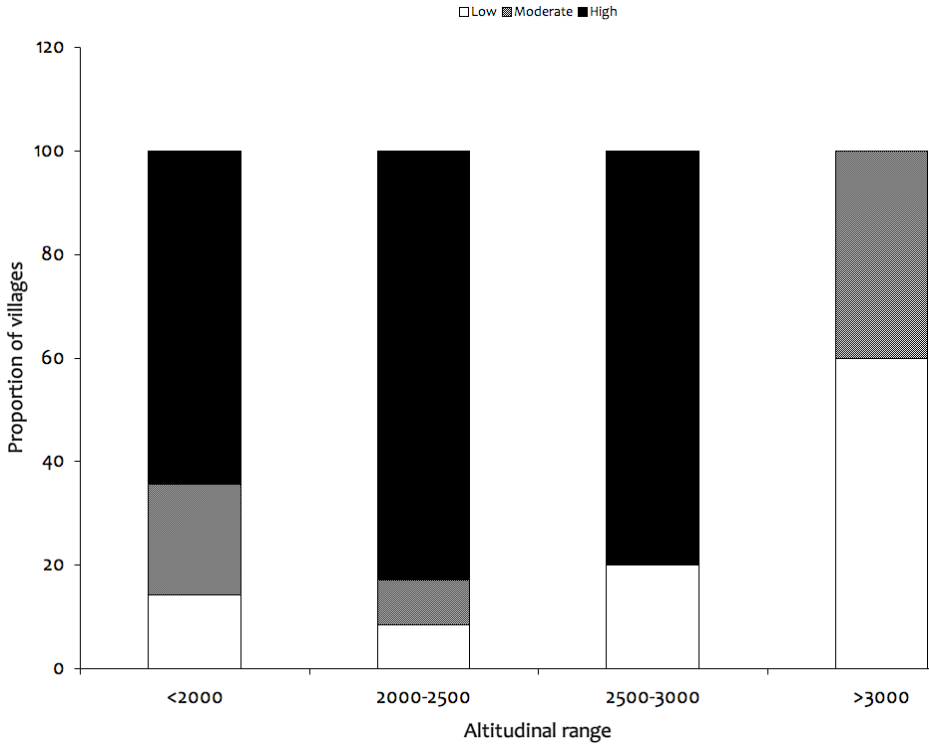


Figure 4. Altitudinal distribution of the intensity of crop damage by the Arunachal macaque *Macaca munzala*. The stacked bars represent proportion of villages with 'low', 'moderate' or 'high' crop damage levels within each altitudinal category. The number of villages surveyed in each zone, starting with the lowest altitudinal zone, was 14, 20, 15, 8, and 7, respectively. Intensity of crop damage appears to be similar in all zones except the high altitudes where both agriculture as well as macaque density are limited.

of 244 respondents could not offer an opinion. Based on the majority of the remaining responses, we found the intensity of conflict with macaques to be high in five of the six villages. The only exception was the high-altitude Thingbu village where conflict with macaques was reported to be very low, and where, due to their religious beliefs, the village council imposes a fine of INR 1000 on anyone hunting macaques. Thingbu is a largely pastoral village with very little cultivation. In the other five villages, a high level of conflict was reported by 87 to 100 % of the respondents (Table 2).

Half of the respondents reported macaque damage to all crops, while the other half reported damage mainly to maize and millets. Buckwheat, which

Table 2. Intensity of human-macaque conflict reported by 237 respondents in six villages of western Arunachal Pradesh where detailed surveys were carried out. The intensity is depicted as the percent of respondents in each category ('low', 'medium', 'high').

Village	Low	Medium	High	Number of respondents
Rho	0	0	100	58
Shyro	13	0	87	46
Jangda	0	0	100	53
Morshing	0	0	100	29
Berchii	0	0	100	12
Thingbu	89	3	8	39

is limited in cultivation, was reportedly the least affected crop. Crop damage was reported to occur throughout the year, with maximum damage between July to September. We could not reliably estimate the extent of crop losses in terms of yield or money, though a few people ($n = 8$) estimated the average loss to be between INR 3250 to INR 4600 (c. US\$ 70 to 100) per family per year.

In only two villages, a majority of the people (92 %) acknowledged the occurrence of retaliatory killing of the macaques. In the other three villages where high levels of conflict were reported, people completely denied macaque persecution in one, while in the other two, some of the respondents (3 and 11 %) acknowledged its occurrence. Overall, only three of the respondents admitted to killing macaques themselves. In the four villages where persecution was confirmed, people reported an average of 35 macaques killed over the last five

Table 3. Persecution of macaques in retaliation against crop damage in six villages of Western Arunachal Pradesh. The first data column (occurrence of persecution) shows the percent of respondents ($n = 238$) from each village that confirmed that macaques were killed in their area. We also summarise the mean number of instances of macaque killing reported from each of the six villages over the last five years (SD = standard deviation; N = number of respondents reporting instances of macaque killing).

Village	Occurrence of macaque persecution	Number of macaques killed		
	Percent	Mean	SD	N
Rho	92	9	3.0	5
Shyro	0	-	-	0
Jangda	11	11	4.0	3
Morshing	3	4	-	1
Berichi	92	11	2.1	11
Thingbu	0	-	-	0

years (Table 3). Snaring was the most commonly reported method employed to kill macaques, though guns and bow-arrows were also used. In most cases, the carcass was reportedly thrown away. During our surveys, we twice came across instances where the carcass was either hung on trees near crop fields or displayed prominently close to habitation, presumably to deter further crop-raiding by the troops. We also recorded one instance where the carcass of an adult male that had been killed after it had entered a house was to be cooked for treating sick livestock. We procured this specimen; it was then treated, measured, and deposited at the State Forest Department, for preservation at the State Forestry Research Institute, Itanagar, Arunachal Pradesh for preservation as a type specimen (Chapter 2).

During our surveys, we also recorded seven captive individuals of the Arunachal macaque, kept as pets, in different villages; these were all females and included an adult, five juveniles and an infant (Appendix 2).

Discussion

Tawang has the highest human density amongst all the districts of Arunachal Pradesh. There is widespread cultivation in the region, and there has been considerable forest degradation and loss (Mishra *et al.* 2004). Yet, it supports a significant population of the Arunachal macaque. The fact that over three-fourths of our sightings of the Arunachal macaque were in human-modified landscapes suggests that the species may be tolerant of some level of anthropogenic habitat modification. This is consistent with the remarkable ecological adaptability and behavioural flexibility that characterise a majority of the 21 species within the genus *Macaca*. The genus occupies a very wide range of habitats, and amongst primates, is second only to humans in terms of its global geographical range (Fa and Lindburg 1996). Species such as the rhesus macaque *Macaca mulatta* and the bonnet macaque *M. radiata* represent extreme examples of macaques that can continue to persist even inside towns and cities (Malik and Johnson 1994, Sinha 2001, Imam *et al.* 2002). The ability of these species to use extra food from crop fields or anthropogenic waste from human settlements can potentially off-set the effects of habitat degradation and can result in the stability or even growth of such populations (Zhao 1999).

During our surveys, we could confirm the presence of the Arunachal macaque up to 3000 m, and its seasonal occurrence was reported up to 3500 m, making it amongst the highest-altitude macaques in the Indian subcontinent

(Menon 2003, Sinha *et al.* 2005). From our data, it appears that the species is largely a mid to high elevation primate, with maximum abundance in the 2000-2500 m zone (Figure 2). However, this pattern of high abundance of the Arunachal macaque particularly between 2000-2250 m is presumably brought about by the data from the high density Zemithang area where the species is not hunted. Although our surveys covered a distance of 1000 km thrice, 41 % of the total individuals we sighted were restricted to a small area of 10.6 km² in the Zemithang region. We therefore believe that provided hunting can be controlled, the species could attain much greater abundance in the other altitudinal zones as well, except perhaps in the highest and lowest zones where it will presumably compete with other species such as the Assamese and the rhesus macaques.

Crop damage by macaques is not commonly reported as a problem from other parts of Arunachal Pradesh, possibly because macaques are eaten in most areas and the surviving troops are extremely shy and retiring. Traditionally, shifting cultivators have combined cultivation with hunting of crop-raiding animals for food (Naughton-Treves *et al.* 1998). As hunting is not as prevalent in Tawang and because the local Monpa community does not generally eat primates, conflicts over crop damage by wildlife are common here. Amongst different wild taxa, wild pigs and macaques were reported to cause the highest amount of crop damage in our study area. Interestingly, our preliminary data indicate that the intensity of reported crop damage by the Arunachal macaque across altitudinal zones does not seem to be correlated with its abundance. The reported patterns of crop damage were similar across the altitudinal categories even under low macaque abundance (except in the highest altitudes where the level of conflict was low). Crop raiding animals generally do not give up feeding on wild food, but expand their diet to include crops (Naughton-Treves *et al.* 1998). Given that crops generally have greater nutritive and lower toxin levels compared to their wild relatives (Sukumar 1990), agricultural fields presumably are attractive patches of seasonally abundant, high-quality food for the macaques. Therefore, even under conditions of low density and high per capita availability of natural food, the macaques can be expected to raid crops and come into conflict with people, as long as crops are available in the vicinity of their natural habitats.

Despite relatively low levels of hunting in Tawang as compared to other parts of Arunachal Pradesh, our surveys confirmed the occurrence of retaliatory persecution of the macaques, with at least 35 instances of reported macaque

killing over the last five years in a sample of six villages. The practice of keeping infants and juveniles as pets also acts as an added incentive to hunting (Chapman and Peres 2001). Furthermore, during our surveys, the local people reported that people from other tribes living or posted in Tawang hunt primates for food and sport. Thus, although seemingly adaptable to habitat change, the Arunachal macaque is potentially seriously threatened by hunting. Finally, the low infant to adult female ratio recorded during our surveys suggests that not all adult females breed at any given time, and that females do not give birth every year, making the species further vulnerable to hunting.

Our preliminary work brings to light both the challenges as well as the opportunities for the conservation of the Arunachal macaque. It appears that conservation efforts for the macaque will need to focus on a landscape that has seen considerable anthropogenic impacts. Amongst the most important current research needs is a better understanding of the patterns and intensity of crop raiding, which could enable the designing of appropriate conflict mitigation strategies. Although it is unlikely that conflicts can be eliminated, interventions are needed to minimise crop damage as well as offset losses. The potential of a variety of interventions needs to be assessed; these could include the adoption of alternate buffer crops, use of deterrents, better crop protection measures, habitat management in the vicinity of villages, and the introduction of crop compensation or insurance programmes.

Our work suggests that although the Arunachal macaque may tolerate some amount of habitat change, the issue of hunting must be addressed urgently. In the absence of hunting, the population density attained by the species, as exemplified in the Zemithang area, can be remarkably high, comparable with the highest densities reported for macaques in general (e.g. *Macaca fascicularis*: 15-39 km⁻², *M. nemestrina*: 5 km⁻², Chapman 1995; *M. thibetana*: 24-56 km⁻², Zhao 1999; *M. sylvanus*: c. 20 to 29 individuals km⁻², Camperio Ciani *et al.* 2000; *M. fuscata*: 13-27 km⁻², Hanya *et al.* 2005).

The Arunachal macaque is the first new macaque species to be described after a gap of over a century, the last macaque to be described being the Pagai macaque *M. pagensis* of Indonesia by Miller in 1903. This is a matter of pride for the state of Arunachal Pradesh, arguably India's richest state in terms of its biodiversity. Appropriate conservation education efforts are required to communicate the global significance of the Arunachal macaque to the local communities in this state.

The species, in fact, has the potential to become a tourism resource as well as a conservation flagship (Alexander 2000, Hill 2002). Given the Buddhist beliefs of the Monpa community and the absence of a very strong hunting culture amongst them, we believe that a multifaceted programme that addresses these several issues will be able to garner the local people's support for the conservation of the Arunachal macaque.

Acknowledgements

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4. FORAGING ECOLOGY AND SOCIAL BEHAVIOUR OF THE ARUNACHAL MACAQUE – A PRELIMINARY STUDY

R Suresh Kumar, Charudutt Mishra and Anindya Sinha

Abstract

The Arunachal macaque *Macaca munzala* was discovered in 2003 from the high altitudes of western Arunachal Pradesh, but virtually nothing is yet known of this new macaque species. In order to generate scientific knowledge on this primate, a field study was conducted to collect information on its ranging patterns, diet and behaviour. Two multimale multifemale troops were observed for a period of 112 hours in the Zemithang valley of Tawang district. The two troops, consisting of 22 and 13 individuals respectively, spent, on an average, 48 % of the observed time in moving and foraging, 36 % in sitting and resting, and 16 % in social interactions. Foraging alone accounted for 29 % of the time-activity budget and was the major activity of the macaques throughout the study. The troops had distinct territories with home ranges of 28 ha and 16 ha respectively, much smaller than those of other macaque species studied in similar environments elsewhere. The macaques ranged largely in the secondary scrub habitat in the study area, where they were observed to feed mainly on *Elaeagnus parvifolia* and *Erythrina arborescens*. Although fruits of the former species constituted more than 65.8 % of the overall diet, this largely frugivorous diet is likely to be seasonal. Our preliminary results suggest the ranging and foraging behaviour of the Arunachal macaque to be largely in response to food resource availability. The species also appears to be a typical member of the *sinica* species-group of the genus in exhibiting a matrifocal society with tolerant social relationships.

Introduction

The Arunachal macaque *Macaca munzala*, discovered from Tawang and West Kameng districts of western Arunachal Pradesh is a species of the high altitudes of the Eastern Himalaya, occurring between 2000 to 3500 m (Sinha *et al.* 2005), the highest altitude reported for the occurrence of any macaque in the Indian subcontinent (Menon 2003). Belonging to the *sinica* species-group, the Arunachal macaque closely resembles the Assamese macaque *M. assamensis* in external morphology (Sinha *et al.* 2005). It is also believed to be sympatric with the Assamese macaque, a species distributed more at lower altitudes, occurring

mainly in the subtropical broad-leaved evergreen forest between 150 m to 1900 m, and extending to a maximum of 2750 m (Lekagul and McNeely 1977, Fooden 1982, Nowak 1999).

Not much is known yet about the field biology of the Arunachal macaque and how it differs in its behavioural ecology from the other members of the species-group. It is also not known whether it is a habitat- or diet specialist or a generalist, as is the Assamese macaque, and how far it ranges, given its distribution in the high altitudes where resources are limiting during certain times of the year. Such information is crucial not only in understanding its evolutionary history but also in evaluating the conservation status of this newly discovered primate. This becomes particularly important as the Arunachal macaque is thought to be possibly threatened due to its conflict with the local people over crop depredation and occasional hunting (Chapter 3). This led to a short two-month study on two troops of the Arunachal macaque, carried out during July-August 2005, to investigate the ranging patterns, foraging ecology and time-activity budget exhibited by the species.

Methods

Study area

After initial surveys in the Tawang district of Arunachal Pradesh, the Zemithang valley (27°42'N, 91°43'E), located approximately 100 km northwest of Tawang town, was chosen for this investigation (Figure 1). Four Arunachal macaque troops were initially identified within a two-km² area in the valley, and later during the study, two other troops were noticed in the area. Two of these were selected for the intensive study. It is noteworthy that the troops in this area were relatively less shy and allowed for closer observation than elsewhere in the district, possibly, due to a general ban on hunting of wildlife in the area (Chapter 3).

The altitude within the study area (Figure 1) ranged from 2000 to 2400 m and comprised of secondary scrub vegetation, forested areas (subtropical broadleaved evergreen forest) and agricultural fields. The secondary scrub vegetation was dominated by *Erythrina arborescens*, *Elaeagnus parvifolia* and *Debregeasia longifolia*, with *Pteridium* – a species of fern, and *Aconogonum molle* forming the ground cover. A large forested patch occurred west of the river Nyamjang Chu, which flows through the study area; the common tree species

here were *Schima wallichii*, *Alnus nepalensis*, *Rhus javanica*, *R. wallichii*, *Populus* sp., *Engelhardia* sp., *Quercus griffithii* and *Q. lanata*; while shrubs like *Aconogonum molle* and *Viburnum* sp. formed the dense undergrowth. Agricultural fields in the area were usually close to settlements and the crops grown included mainly millet and maize. Heavy to moderate rain showers occurred throughout the study period while foggy conditions prevailed regularly early in the day. Average temperatures of 17°C and 35°C were recorded during early morning and mid-day respectively during the study period.

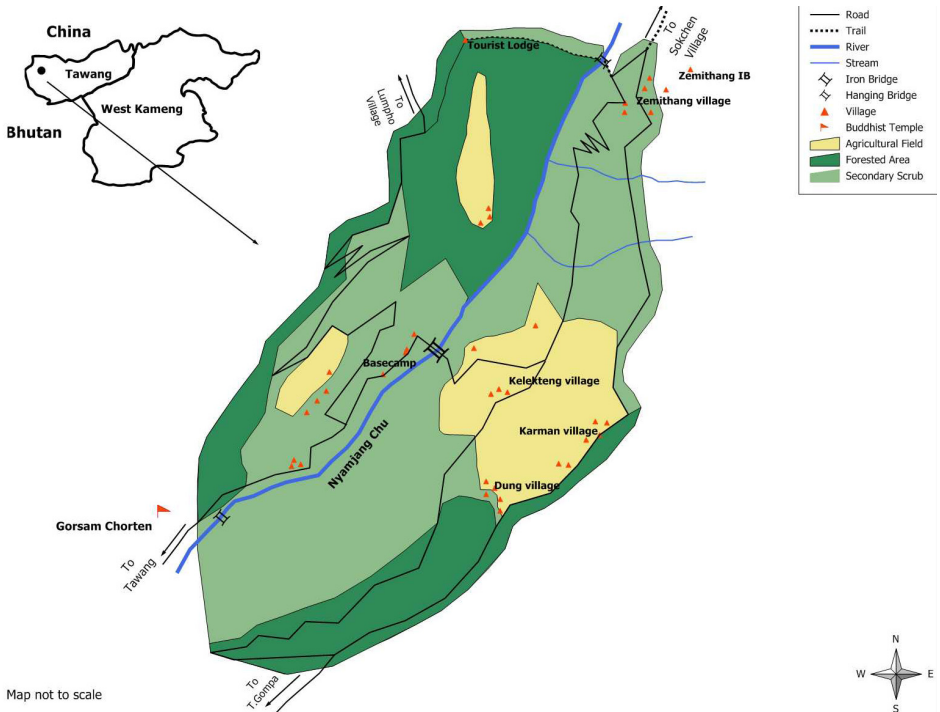


Figure 1. A schematic representation of the study area in the Zemithang region of Tawang district.

Study troops

Two troops, respectively called the Bridge Troop and the Rock Troop owing to certain features of their home ranges, were chosen for this study. The Bridge troop was larger with 22 individuals and comprised of five adult males, six adult females, four subadults and seven juveniles of both sexes. All six females in the troop had infants when this study was begun, although one of the infants was left behind in

a kitchen garden in Zemithang village in June, when the troop was being chased away by people, and was later adopted as a pet by a villager. The presence of only five infants with six adult females was one of the notable features used to identify and locate the troop.

The smaller Rock troop had 13 individuals comprising of three adult males, four adult females, two subadult females and four juveniles of both sexes. One of the subadult females had half of her left forelimb missing and this was one of the characters used in the identification of this troop. Only one female had an infant in this troop and she appeared to be younger than the other three females in the troop. Of the four juveniles in the troop, one appeared younger than the others and an adult female was regularly observed to suckle this infant.

Data collection and analysis

Observations on the two troops were made either from close distance (50-75 m) by following them on foot or from selected vantage points in the area using a pair of 8 x 40 binoculars. Information on time-activity budgets, ranging patterns and foraging ecology of the two troops was collected over two months, July and August 2005, during regular follows spread over each month. The troops were usually active between 0600 and 1800 H, and observations were thus carried out within this time period. Due to the inhospitable terrain, however, the troops could be followed throughout the day only on a few occasions. The rest of the data were collected from sporadic scan sampling opportunistically over each day. Whenever possible the troops were located at their sleeping sites during the late afternoon and followed from early morning the next day as they left the site. Only group scan sampling (Altmann 1974) was carried out and data on both behaviour and ecology were recorded at five-minute intervals.

The behaviours that were considered in the time-activity budget included sitting, resting, moving, foraging, and social interactions such as allogrooming, autogrooming, playing, mating, aggression, and alarm calling. Resting refers to those observations when the monkeys were in the trees sleeping or just sitting in the shade of the foliage during the day, while sitting was when monkeys were found sitting on the ground or on large boulders in the area, not partaking in other activities such as grooming or foraging. Visibility was a problem as the entire troop or a few individuals often moved into the undergrowth or into forested tracts,

where it was not possible to follow them further. On these occasions, data were collected only from those individuals that were visible during each scan.

When feeding, information on the plant species and the parts eaten by individual macaques was noted. When macaques were observed feeding on the ground, the location was searched after the macaques had left the area in order to investigate what they had fed on. Food plants and other plant samples from the area were collected and identified using Polunin and Stainton (1987). The locations of the troop and the paths traversed by it while moving and foraging were recorded during each observation period using a GPS and used to map the home ranges of the troops. Two different home range estimates were obtained, one using the minimum convex polygon (MCP) method (the program CALHOME; Kie *et al.* 1996) and the other by directly joining the outermost points where each troop was located, using GIS. Information on other troops occurring in the area were also recorded whenever possible.

After the initial exploration of the data, it was decided to pool the scan samples (Table 1) into three sessions – Morning (0430 to 1000 H), Mid-day (1000 to 1500 H) and Afternoon (1500 to 1830 H) respectively, as the data collected were often only by sporadic scan sampling and there were no data available for certain times of the day. The data on the two troops for the two months were also analysed together to obtain certain generalisations for the species, particularly as the study was conducted over only a short period of time.

Table 1. Scan hours and scan samples for the study troops during July-August 2005

TROOP	Session	July		August		Total	
		Hours	Samples	Hours	Samples	Hours	Samples
Bridge	Morning	12.17	125	08.50	95	20.67	220
	Mid-day	08.83	127	05.25	65	14.08	192
	Afternoon	02.25	17	07.17	84	09.42	101
	Total	23.25	269	20.92	244	44.17	513
Rock	Morning	04.75	39	14.00	165	18.00	204
	Mid-day	07.67	126	20.42	235	28.01	361
	Afternoon	07.58	80	13.25	134	20.83	214
	Total	20.00	245	47.67	534	67.67	779
Overall		43.25	514	68.59	778	111.84	1292

Results

Home range and habitat associations

In order to map troop home ranges, 36 different locations for the Rock Troop and 46 locations for the Bridge Troop were obtained, with the troops often being found in many of these locations repeatedly during the study.

The two troops had distinct home ranges, which overlapped with each other partially. The larger Bridge Troop had an approximate home range size of 24 to 28 ha (estimated by the GIS and the MCP methods respectively), while that of the Rock Troop was estimated to vary from 11 to 16 ha by the same methods. The extent of overlap between the two home ranges was estimated to be 3.5 ha but the two troops were never observed simultaneously here. The Bridge Troop mainly ranged along the river Nyamjang Chu while the Rock Troop occurred only on the slopes east of the river (Figure 2), with an average daily ranging distance of approximately 1.5 km for both troops.

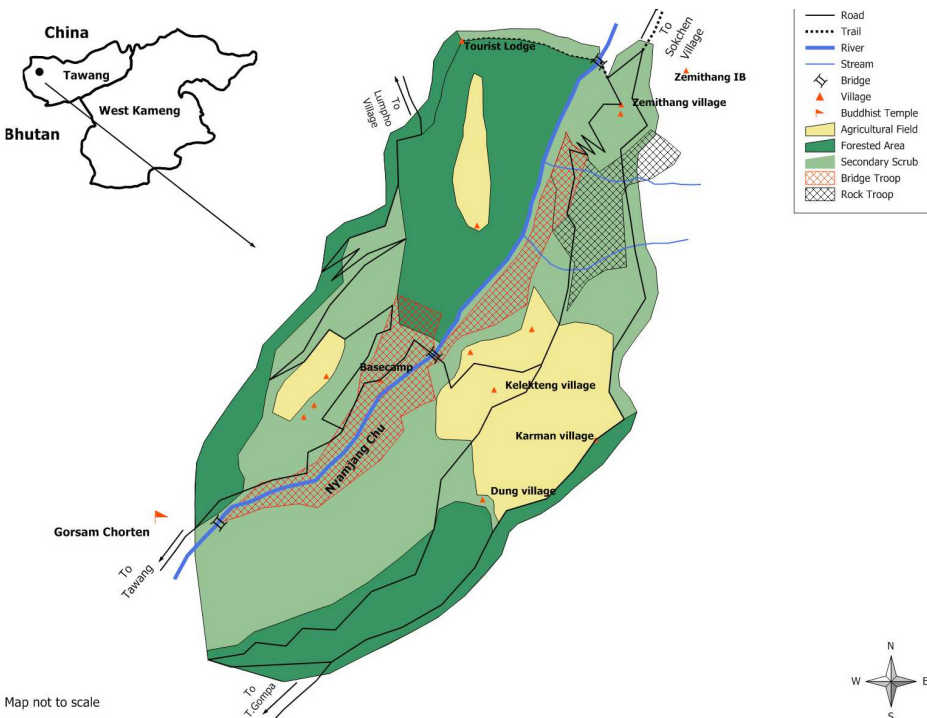


Figure 2. Map of the study area showing the home ranges of the two study troops, calculated using the minimum convex polygon method.

Most locations of the two troops, observed during July and August, were in a secondary scrub habitat with similar ecological characteristics (Figure 2). Only occasionally (5 % of the observed locations) did the Bridge troop move into the forested area west of the river Nyamjang Chu. The Rock Troop, in contrast, ranged only in secondary scrub and was never observed to visit the forested area on the slopes above its home range. The altitudinal range of the Bridge Troop varied from 1975 to 2100 m, while that of the Rock Troop ranged from 2050 to 2250 m.

Time-activity budget

Instantaneous scan sampling of the two study troops yielded a total of 12,017 individual behavioural records during 1292 scan samples over a total time of c. 111 h (Table 1). Of these, 6436 and 5581 were individual behavioural records of the Bridge and Rock Troops respectively.

The two study troops spent, on an average, 48 % of the observed time in moving and foraging, 36 % in sitting and resting, and only 16 % in social interactions (Figure 3). Foraging alone accounted for about 29 % of the time-activity budget and was the major activity of the macaques throughout the study. The two troops exhibited similar time-activity budgets over the study period, with only the proportion of time spent in foraging being significantly different (Mann-

Table 3. List of food plants consumed by the Arunachal macaque during the study. The percentage contribution to the diet is given for only those species that were observed to be eaten during the two-month intensive study.

Species	Family	Habit	Parts eaten	Percentage contribution
<i>Magnolia campbelli</i>	Magnoliaceae	Tree	Base of petal	-
<i>Rhus wallichii</i>	Anacardiaceae	Tree	Fruit	0.1
<i>Coriaria napalensis</i>	Coriariaceae	Shrub	Fruit, new leaf	-
<i>Erythrina arborescens</i>	Fabaceae	Small tree / shrub	Leaf, young shoot, flower, pod, bark	22.3
<i>Rubus ellipticus</i>	Rosaceae	Shrub	Fruit, inner stem	-
<i>Fragaria nubicola</i>	Rosaceae	Herb	Fruit	-
<i>Prunus cerasoides</i>	Rosaceae	Tree	Leaf	-
<i>Pyrus</i> sp.	Rosaceae	Tree	Fruit	-
<i>Selinum tenuifolium</i>	Apiaceae	Herb	Whole plant	0.6
<i>Viburnum</i> sp.	Sambucaceae	Shrub	Fruit	1.6

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Species	Family	Habit	Parts eaten	Percentage contribution
<i>Cirsium verutum</i>	Asteraceae	Herb	Flower	-
<i>Rhododendron keycei</i>	Ericaceae	Small tree	Flower	-
<i>Primula denticulata</i>	Primulaceae	Herb	Peduncle	-
<i>Pteracanthus urticifolius</i>	Acanthaceae	Shrub	Young leaf, shoot	-
<i>Persicaria capitata</i>	Polygonaceae	Herb	Stem	0.2
<i>Fagopyrum dibotrys</i>	Polygonaceae	Herb	Leaf, stem	-
<i>Aconogonum molle</i>	Polygonaceae	Shrub	Stem	1.4
<i>Elaeagnus parvifolia</i>	Elaeagnaceae	Shrub	Flower, fruit	65.8
<i>Elaeagnus pyriformis</i>	Elaeagnaceae	Climbing shrub	Fruit	-
<i>Glochidion sp.</i>	Euphorbiaceae	Shrub	Fruit	-
<i>Laportea terminalis</i>	Urticaceae	Herb	Young leaf, shoot	-
<i>Debregeasia longifolia</i>	Urticaceae	Small tree / shrub	Young leaf, fruit	0.4
<i>Morus acidosa</i>	Moraceae	Small tree	Young leaf, shoot	1.1
<i>Salix sikkimensis</i> or <i>S. daltoniana</i>	Salicaceae	Shrub	Catkin	-
<i>Hedychium sp.</i>	Zingiberaceae		Inner stem, flower	-
<i>Arundinaria sp.</i>	Poaceae	Bamboo	Bamboo leaf	-
<i>Pteridium sp.</i>		Fern	Rhizome	-
Species of mushroom		Mushroom	Whole	-
Unknown		Herb	Leaf	0.3
Unknown		Shrub	Fruit	-

Whitney U-test, $p < 0.05$; Figure 3); the larger Bridge Troop foraged more than did the smaller Rock Troop. A comparison of the performance of the different behaviours across the day revealed a significant difference in the distribution of resting and sleeping from that shown by the other behaviours (chi-square test, $\chi^2 = 11.9$, $df = 2$, $p = 0.003$; Figure 4). The study troops preferentially rested and slept during the late morning and mid-day, usually between 0800 and 1200 H.

Allogrooming was the most common social interaction observed, with approximately 12 % of all individuals indulging in it, on an average, across the scans. This was followed by playing (3 %), while other interactions such as autogrooming, agonistic interactions and sexual behaviour accounted for less than 1 % of all the behaviours displayed. Our study yielded 214 records of allogrooming,

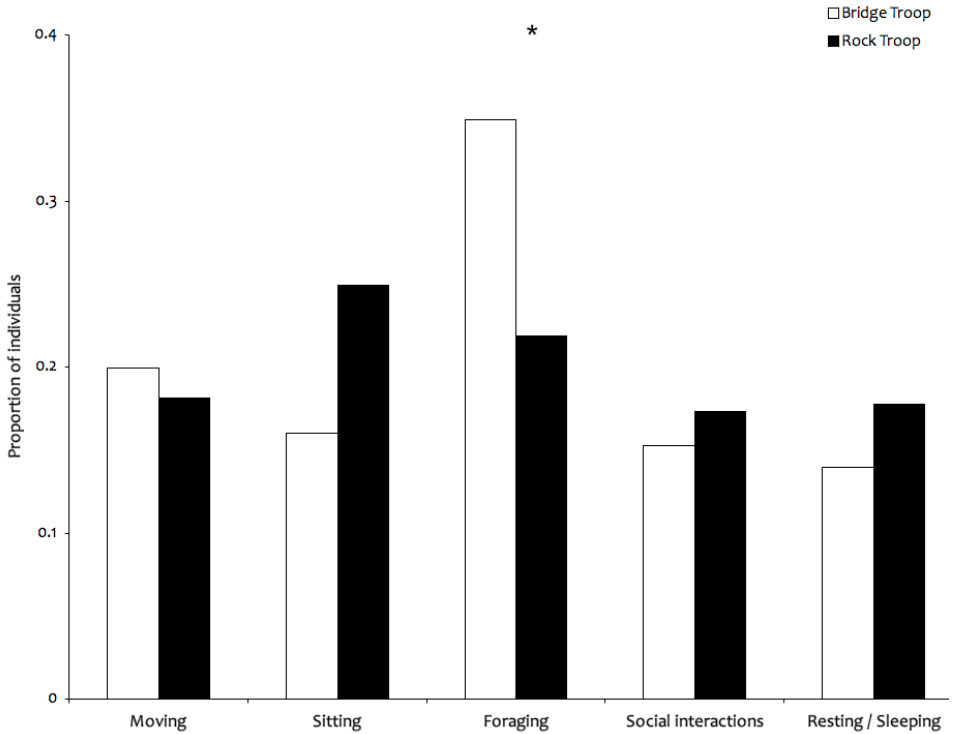


Figure 3. Time-activity budgets of the two study troops during July-August 2005. The asterisk indicates a significant difference between the two troops in the proportion of animals that foraged during the study period (Mann-Whitney U-test, $p < 0.05$).

and on virtually all occasions regardless of the age-sex category of the participating individuals, grooming was reciprocated. Adult males and females distributed their grooming differently across the age-sex categories of the recipients (G-test of independence, $G = 50.08$, $df = 3$, $p < 0.001$), tending to preferentially allogroom adult members of the same sex (Table 2). Subadult and juvenile individuals too distributed their allogrooming differently from each other ($G = 8.83$, $df = 3$, $p < 0.05$) with most juveniles preferring to groom adult females (Table 2).

Agonistic interactions occurred at very low levels within the study troops, with 0.3 % of individuals displaying, on an average, mainly mild non-contact aggression, including open-mouth threats, stares and eye-flashes. It was not possible to compare the levels and nature of such interactions between the two study troops as they occurred very rarely.

Some of the other behaviours that were observed in the study troops, but the

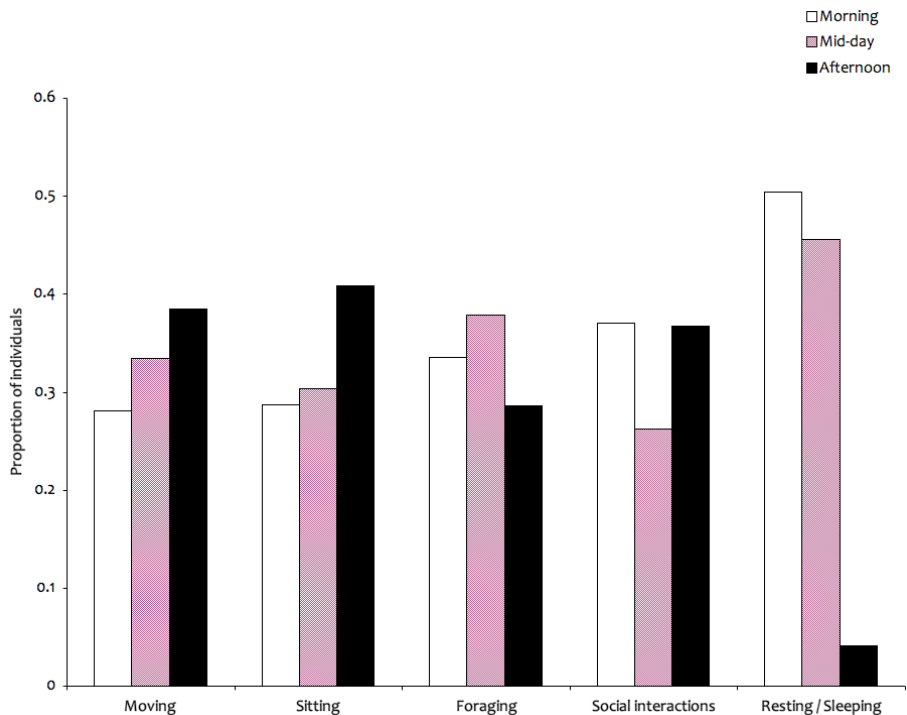


Figure 4. Distribution of different behaviours, displayed by the study troops, across the day during July–August 2005. The asterisk indicates a significant difference in the distribution of resting and sleeping over the different times of the day from that shown by the other behaviours (chi-square test, $\chi^2 = 11.9$, $df = 2$, $p = 0.003$).

Table 2. Allogrooming events observed across age-sex classes in the study troops

Actors	Recepients			
	Adult males	Adult females	Subadults	Juveniles
Adult males	20	4	16	12
Adult females	6	55	14	18
Subadults	8	14	5	3
Juveniles	2	30	5	2

levels of which could not be measured accurately owing to their relative rarity, included presenting by both adult and subadult females to adult males, mounting between adult and subadult males, branch-shaking by dominant males and sexual behaviours such as the inspection of females, which were presumably sexually

cycling, by males and sexual mounting of adult or subadult females by adult males.

Diet and feeding behaviour

Approximately 40 species of plants were observed to be consumed by the Arunachal macaque, with a few of these forming more than 75 % of its diet during the study period (Table 3; see also Appendix 3). Of the total of 3452 individual feeding records obtained for the species, the food items in 119 of them (3.4 %) could not be identified as the macaques were largely feeding on the ground and the parts eaten by them could not be found or identified. It is noteworthy that the macaques were observed to only feed on plant matter during the study, though local people did report insect larvae and earthworms to be part of their diet.

The fruits of *Elaeagnus parvifolia*, a deciduous shrub fruiting extensively during July-August, formed the major constituent of the diet of the troops during the study period, accounting for 65.8 % of the feeding observations, followed by *Erythrina arborescens* (22.3 %; Table 3). During April to June, prior to the intensive study period, however, the macaques mainly fed on the leaves, leaf stalks, bark, pith and the flowers of the latter species. Given the short duration of the intensive study, most plant species were observed to be consumed by the study troops only sporadically; an exhaustive analysis of the entire diet composition for the species was thus not possible. Our observations *ad libitum*, however, did yield some noteworthy records. One of the other troops in the study area, for example, was found to feed on mud from an exposed slope alongside a stream on one occasion.

A month-wise analysis of the feeding records of the two troops showed an increase in the consumption of *E. parvifolia* during August, when the fruits of this

Table 4. Percentage contribution of the major food plants to the diet of the two troops during July-August 2005. The figures in brackets indicate the number of feeding records for that month.

Major food plants eaten	Bridge Troop		Rock Troop	
	July (1054)	August (1159)	July (465)	August (774)
<i>Erythrina arborescens</i>	36.0	16.6	41.7	11.8
<i>Elaeagnus parvifolia</i>	31.7	75.8	52.4	87.3
<i>Viburnum</i> sp.	4.1	1.0	3.9	0.2
<i>Aconogonum molle</i>	4.7	0.8	-	-
<i>Morus acidosa</i>	4.8	-	-	-
Millet	3.9	-	-	-

species had ripened fully and were easily available, with a simultaneous decrease in the intake of *E. arborescens* and *Viburnum* sp. (Table 4), the fruiting season of the latter species also having come to an end.

Millet was represented in the diet of the Bridge Troop, as this troop occasionally ventured into the crop fields in the area. This troop also raided fruit orchards, scavenged on human-generated garbage, and rarely raided the kitchens of houses within its home range.

Sleeping sites

The Bridge Troop was observed to use nine sleeping sites during the study period, all of which were located between large boulders with dense shrubby undergrowth, overlooking the river Nyamjang Chu. The average height of the sleeping sites was 15 m amidst vegetation with a canopy cover of c. 25 %. Two of the nine sleeping sites of this troop consisted of a bare, relatively unprotected, *Prunus cerasoides* tree, which the individuals used even in heavy rain, and a neighbouring *Rhus wallichii* tree; all the other sites were in secondary scrub habitat. The Rock Troop, on the other hand, used only a single sleeping site in stunted shrubby vegetation on a cliff face, high up on a slope, overlooking the Zemithang village (see Figure 4).

Discussion

Primates that exploit highly dispersed and unpredictable food supplies are known to have larger home ranges than species feeding on dense resources that are evenly distributed and predictably available (Oates 1987). Larger home ranges would, in turn, necessarily entail relatively greater foraging distances and higher proportions of travelling time in the daily activity budget of individuals.

The two troops of the Arunachal macaque did not appear to have large home ranges, at least during the months of July and August when this study was carried out, as compared to those of other macaques living in higher latitudes and in cold temperate regions. Rhesus macaque populations occurring in such environments, for example, range over large areas of eight to 22 km² (Lindburg 1971, Richard 1985, Qu *et al.* 1993, Southwick *et al.* 1996), while a population of Japanese macaques in a cold temperate forest had a larger home range still (Azuma 1985). The small home ranges of the Arunachal macaque were correlated with high levels of foraging activity but relatively small distances travelled daily in search of food. Such short ranging distances were possible because of the ready availability

of food resources with both *Elaeagnus parvifolia* and *Erythrina arborescens*, the two principal food plants of the macaque during July and August, completing their full growth phase during these two months.

The inter-troop variation in home range size of the two study troops could be due to differences in their group size, a finding reported in other species of macaques as well (van Schaik *et al.* 1983, Maruhashi and Takasaki 1996, Southwick *et al.* 1996). The variation in the number of sleeping sites across the two troops also reflects the difference in home range size, possibly mediated by the availability of suitable roosting sites within them. The Rock Troop thus had a small home range close to the cliffs where it roosted, while the Bridge Troop ranged along the river Nyamjang Chu and used several tall trees overlooking the river as alternative sleeping sites. The selection of sleeping trees along river edges and cliffs appear to be a behaviour associated with predator avoidance, as has been reported for *M. fascicularis* (van Schaik *et al.* 1996), although this needs further confirmation.

The involvement of a relatively greater proportion of the troop individuals in foraging and moving, exhibited by the Bridge Troop over that by the smaller Rock Troop, could be due to three factors. It is possible that the larger size of the former troop required individuals to move and forage more simply because it was difficult to obtain adequate food for a greater number of animals. Alternatively, the frequent occurrence of this troop close to crop fields and human habitations may have led to them being chased more often by the local people or harassed by village dogs. The Rock Troop, in contrast, rarely ventured close to human settlements. Thirdly, the overlap in the home range of the Bridge Troop with those of three other neighbouring troops may have caused the individuals of this troop to intensify their foraging activity and perhaps even move more to avoid interacting with the members of those troops. The Rock Troop, in contrast, had a small home range that overlapped partially with the Bridge Troop but was far away from those of the other troops in the Zemithang area.

Our preliminary observations of allogrooming and other affiliative interactions *ad libitum* suggest that the Arunachal macaque may have a matrifocal society, characterised by a close association between grooming and social bonding, as exemplified by the Assamese macaque and other macaque species as well (Cooper and Bernstein 2000). The extremely low levels of observed intra-troop aggression also provide some evidence for the relatively tolerant social relationships that



prevail in this society, again as has been proposed for the *sinica* species-group of this genus (Cooper and Bernstein 2002). More detailed behavioural observations are, however, required before a complete characterisation of the Arunachal macaque society is attempted.

Sexual behaviour, including copulations with ejaculation, was only observed in the Rock Troop, and not in the Bridge Troop, during the study period possibly because three of the four adult females of this troop were without infants, with the fourth female occasionally nursing a young juvenile. The six adult females of the Bridge Troop, on the other hand, had dependent infants, all of which appeared

to form a cohort born in the spring (April-May) of that year. Fooden (1982) has reported a spring birth peak in *M. assamensis* in Thailand, while Zhao (1996) observed births during March in *M. thibetana*. Whether there exists a clear birth season in Arunachal macaque is not very clear, as few other troops in the area had infants when observed casually earlier, during the month of February. The inter-birth interval in this species also remains unknown though our preliminary observations suggest a period of two years (Sinha, pers. obs.), a feature that it potentially shares with *M. thibetana* (Zhao 1996). *M. assamensis*, on the other hand, has an inter-birth interval of a year (Fooden 1982).

The high proportion of fruits in the diet of Arunachal macaques observed during the study suggests the species to be principally frugivorous. This, however,

could be influenced by the phenology of the food species as, prior to the intensive study period, the macaques were observed to mainly feed on leaves. Fruit has also been reported to be the principal natural food of *M. assamensis* in Thailand (Fooden 1982). A large number of plant food species has been reported in *M. thibetana*, with leaves being preferentially consumed over seeds and fruits (Zhao 1996). The diet of the Arunachal macaque troops, occurring in forested tracts of the study area, may vary from that of the study troops as well, a hypothesis suggested by our observation that the principal food species of the study troops - *E. parvifolia* and *E. arborescens* – were not commonly found in the forested tracts. A detailed study on the diet of the Arunachal macaque, however, needs to be initiated, as food may be a major limiting resource for the troops during the harsh winter months in the study area.

The continued presence of the focal troops in the secondary scrub habitat of the study area, suggests that the species may be able to successfully adapt to changes in their natural environment, as do many other macaque species. This however, should not be considered necessarily beneficial to the species, as with the steady decline of natural habitats the macaques could become increasingly dependent on human- dominated landscapes, which would, in turn, lead to human-primate conflict (Chapter 3). It is imperative that awareness programmes and mitigation of human-macaque conflict be initiated in cooperation with the local community and regional government departments in Tawang district for the future welfare of the Arunachal macaque.

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5. SYNTHESIS AND FUTURE DIRECTIONS



Our studies on the morphology, anatomy, natural history and molecular phylogeny of the Arunachal macaque *Macaca munzala*, a recently discovered cercopithecine primate inhabiting subtropical broadleaved forests in the high altitudes of western Arunachal Pradesh in northeastern India, clearly reveal it to be an enigmatic species within the *sinica* species-group of the genus *Macaca*. It is an unusual species because although it has close phylogenetic links with the allopatric bonnet macaque *M. radiata* of tropical southern India, its morpho-anatomical affinities lie with the geographically closer Assamese macaque *M. assamensis* and the Tibetan macaque *M. thibetana*, possibly mediated by convergent evolution under similar ecological conditions. What needs to be explored further, however, are the morpho-anatomical and phylogenetic relationships of the Arunachal macaque with the western subspecies of the Assamese macaque *M. a. pelops*, with which it is possibly sympatric but distinct in certain features such as pelage colour and relative tail length.

Our preliminary studies on the ranging, foraging and behavioural ecology of two troops of the macaque in the Zemithang locality of Tawang district, from where the type specimens for the species were obtained, reveal a primate that has

remarkably adapted to the harsh environmental regimes that it has evolved in. It is a generalist in exploiting about 30 plant and fungal species as food sources, intensively foraging over the entire day within small home ranges that often span a variety of habitats (ranging from riverine forest tracts to secondary scrub on steep slopes and agricultural fields close to human habitations). The species occurs in multimale multifemale groups of up to 60 individuals; the social structure appears to be matrifocal with close social bonds and extensive allogrooming between individuals of all age-sex categories, low levels of agonistic interactions, and relaxed sexual relationships. Is there natural variation in the structure and dynamics of the Arunachal macaque society in environments differing in resource availability or even within the same habitat across seasons? How does the nature of social relationships across individuals of different age-sex categories differ in space and time, particularly in relation to ecological variability in resources such as food, sleeping sites and mating partners? Having identified several distinct populations of the species in different areas of Tawang and West Kameng districts in western Arunachal Pradesh, we now propose to initiate a long-term study that will investigate the ecology, behaviour and demography of several troops of the species with identified individuals inhabiting a variety of ecological environments with widely-differing resource availability.

The Arunachal macaque seems to be tolerant of anthropogenic habitat change, but is vulnerable to hunting. The macaques are persecuted largely in response to crop damage, with the practice of keeping them as pets presumably providing an added incentive to hunting. They can nevertheless attain relatively high population densities in the absence of hunting, as was clear from our demographic studies in Zemithang, where the local *Monpa* people do not usually hunt the species for food or sport. This, coupled with the observation that not all adult females reproduce at any given time and that females do not give birth every year, suggests that the species requires immediate protection in human-modified landscapes and that urgent attention needs to be paid to the twin issues of crop damage and retaliatory persecution in certain areas where the macaque lives close to human habitations and agricultural lands. It is, therefore, apparent that conservation strategies for the Arunachal macaque will need to focus on areas surrounding human habitation, generally outside wildlife reserves. Their increasing occurrence in proximity to humans necessitates that the response of macaques to different kinds of human disturbance is understood. The future of

the macaque will also depend on our ability to promote local peoples' tolerance towards them, and imperatively address the issue of crop damage.

In the immediate future, we thus hope to carry out demographic surveys and behavioural observations on different troops of the Arunachal macaque across a gradient of human disturbance, evaluate the behavioural responses of the species to human-macaque conflict, quantify the extent, seasonality, and patterns of crop damage by the primate and assess, in much greater detail, the attitudes and behaviour of the local people in order to suggest possible conflict mitigation measures. The future of this fascinating species is uncertain, and only collective effort of conservationists, manager and local communities can safeguard its survival and welfare in the years to come.

APPENDIX 1. SIGHTING RECORDS OF THE ARUNACHAL MACAQUE IN TAWANG AND WEST KAMENG DISTRICTS, ARUNACHAL PRADESH

No.	Locality	Latitude & Longitude	Date	Troop size	Habitat
1	Gispu-Shakti bridge, Lower Nyamjang Chu Valley	27.60428 N 91.71889 E	19 August 2003	4+	2230 m, degraded broadleaved forest, close to an isolated crop field
	Gispu-Shakti road		27 February 2005	16+	2210 m, degraded Alnus forest
	Gispu-Shakti road		6 March 2005	8+	2100 m, degraded broadleaved forest
2	Zemithang village, Pangchen Valley; Bridge Troop	27.71022 N 91.73150 E	20 August 2003	6+	2180 m, degraded broadleaved forest, close to crop fields
	Zemithang village; Bridge Troop		29 April 2004	17	2180 m, degraded broadleaved forest
	Gorsam-Zemithang bridge; Bridge Troop		7 March 2005	14	2040 m, degraded broadleaved forest
	Gorsam-Zemithang bridge; Bridge Troop		25 April 2005	16	2080 m, riverine forest
3	Gorsam, Upper Nyamjang Chu Valley; Gorsam Troop	27.69719 N 91.72194 E	21 August 2003	18+	2030 m, roosting in the canopy of a riverine forest
	Gorsam; Gorsam Troop		17 July 2005	40+	2100 m, degraded secondary scrub forest
	Gorsam; Gorsam Troop		30 April 2006	28	2100 m, degraded secondary scrub forest
4	Mirba, Mukto, Upper Tawang Chu Valley	27.54531 N 91.95508 E	27 August 2003	5	2620 m, roof of an abandoned hut in a crop field

No.	Locality	Latitude & Longitude	Date	Troop size	Habitat
	Mirba		10 March 2005	13+	2700 m, degraded oak forest
5	Pak Chui, Mukto, Upper Tawang Chu Valley	27.54328 N 92.94244 E	28 August 2003	7+	2670 m, undisturbed oak forest
	Mukto		11 March 2005	14+	2630 m, summer pasture
6	Lower Jang, Upper Tawang Chu Valley	27.57950 N 91.96669 E	1 September 2003	5+	2120 m, degraded open scrub forest
	Jang bridge		3 March 2005	18+	2033 m, degraded open scrub forest
	Lower Jang		4 March 2005	7+	2150 m, degraded oak forest
7	Jang, Upper Tawang Chu Valley	27.57968 N 91.97932 E	23 September 2003	4+	2470 m, broadleaved forest
8	Dushingthang, Upper Tawang Chu Valley	27.63526 N 92.06922 E	23 September 2003	8+	2700 m, broadleaved forests by a steep cliff
9	Nawrok, Lower Namshu Valley, West Kameng	27.22227 N 92.20236 E	26 April 2004	25+	2870 m, sloping grassland by a broadleaved forest
	Chandar, Lower Namshu Valley, West Kameng		21 February 2005	25+	2880 m, degraded oak and pine forest
10	Lhou, Upper Tawang Chu Valley	27.57700 N 91.95661 E	27 April 2004	34	2100 m, degraded open scrub forest
	Lhou		28 February 2005	63+	2057, degraded open scrub forest
11	Gorsam-Muchot road, Upper Nyamjang Chu Valley; Tourist Lodge Troop	27.70806 N 91.72644 E	29 April 2004	16+	2180 m, degraded broadleaved forest
	Gorsam-Muchot road; Tourist Lodge Troop		21 April 2005	20+	2160 m, Schima-Quercus-Alnus forest
12	Shakti-BTK road, Upper Nyamjang Chu Valley	27.61953 N 91.71342 E	29 April 2004	8+	1640 m, degraded broadleaved forest

No.	Locality	Latitude & Longitude	Date	Troop size	Habitat
13	Puchimae, Mukto-Gongkhar bridge, Shakhang Chu Valley	27.52461 N 91.91961 E	30 April 2004	4+	2140 m, degraded broadleaved forest
	Puchimae		10 March 2005	2+	2110 m, degraded <i>Alnus</i> forest
14	Gyamdong, Shakhang Chu Valley	27.53900 N 91.88436 E	1 May 2004	37+	2220 m, sloping grassland by a broadleaved forest
15	Sherbang, Lower Rong Chu Valley	27.55678 N 91.71361 E	5 May 2004	6+	2100 m, adjacent to broadleaved forests
16	Thingbu, Upper Tawang Chu Valley	27.65982 N 92.09818 E	9 May 2004	9+	3000 m, undisturbed conifer forest
	Thingbu		15 September 2005	6+	2830 m, dense oak forest
17	Bomdir, Tawang Chu Valley	27.89594 N 91.53454 E	25 February 2005	11+	2300 m, degraded oak forest
18	BTK-Gorsam road, Lower Nyamjang Chu Valley	27.68803 N 91.71203 E	27 February 2005	5+	2150 m, <i>Alnus</i> forest
	Gorsam		31 March 2006	25	2100 m, degraded scrub forest
19	Shakti, Lower Nyamjang Chu Valley	27.60428 N 91.71911 E	6 March 2005	8+	2060 m, degraded open scrub forest
20	Muchot, Upper Nyamjang Chu Valley	27.71439 N 91.71928 E	7 March 2005	22+	2450 m, degraded open scrub forest
21	Zemithang, Pangchen Valley; Rock Troop	27.70700 N 91.73106 E	7 March 2005	9+	2140 m, degraded secondary scrub forest
	Zemithang; Rock Troop		25 April 2005	9+	2120 m, degraded scrub forest
	Zemithang; Rock Troop		1 July 2005	13	2100, degraded scrub forest
22	Sokchen, Upper Nyamjang Chu Valley	27.72272 N 91.72561 E	8 March 2005	40+	2300 m, degraded open scrub forest
23	Sessa, Bhareli Valley, West Kameng	27.10703 N 92.56748 E	21 April 2005	3+	720 m, tropical wet evergreen forest

No.	Locality	Latitude & Longitude	Date	Troop size	Habitat
24	Hot Springs, below Gongkhar, Tawang Chu Valley	27.55478 N 91.90067 E	23 April 2005	18	1800 m, millet field near Alnus forest, close to the river
25	Thongleng, Lower Rong Chu Valley	27.57017 N 91.79543 E	24 April 2005	9+	2380 m, degraded Alnus forest
26	Jang-B J Gompa Road, Upper Tawang Chu Valley	27.56233 N 91.96556 E	5 May 2005	8+	2700 m, pasture near oak-Rhododendron forest
27	Sumrang, Jang-Thingbu road, Upper Tawang Chu Valley	27.58975 N 91.99275 E	19 May 2005	12+	2320 m, primary oak forest
28	Karsa, Jang, Upper Tawang Chu Valley	27.58211 N 91.97581 E	28 May 2005	2+	2080 m, millet field near Alnus forest
29	Namthengsae, Jang-B J Gompa Road, Upper Tawang Chu Valley	27.56383 N 91.96267 E	20 June 2005	25+	2840 m, pasture near oak-Rhododendron forest
30	Jaswantgarh, Nuranang Valley	27.55494 N 92.00833 E	22 June 2005	10+	3300 m, fir-maple forest
31	Sheroo, Jang, Upper Tawang Chu Valley	27.55869 N 91.85406 E	26 June 2005	3+	2400, degraded oak forest
32	Karman, Zemithang, Pangchen Valley	27.70681 N 91.73453 E	19 August 2005	30+	2200 m, degraded open scrub forest
33	Gorsam-Zemithang bridge, Nyamjang Chu Valley	27.69900 N 91.72306 E	24 August 2005	23	2000 m, degraded open scrub forest
34	Sange, Dirang Chu, West Kameng	27.43836 N 92.11561 E	30 August 2005	1+	2190 m, maize field close to Alnus forest
35	Gorsam-T Gompa Road	27.69719 N 91.73150 E	2 April 2006	4+	2800 m, fir-maple forest

APPENDIX 2. RECORDS OF CAPTIVE ARUNACHAL AND ASSAMESE MACAQUE INDIVIDUALS IN TAWANG AND WEST KAMENG DISTRICTS, ARUNACHAL PRADESH

No.	Date	Location, site of capture & altitude	Sex & age	Name	Head-body length (cm)	Tail length (cm)	Tail to head-body length ratio	Species identity
1	22 April 2004	Bhalukpong Tipi	Male ~1 year+	Bhai	26.6	13	0.49	Assamese macaque (?)
2	26 April 2004	Jang China Bridge (Nuranang), on way to Mago Chu Valley	Female Juvenile, ~1.5 years	Julie	28.3	11.1	0.39	Arunachal macaque
3	30 April 2004	Jorbhey Locally caught, 1950 m	Female ~1 year+	Dandu	-	14	-	Assamese macaque (?)
4	4 May 2004	Thrillum Locally caught, 2750 m	Male ~18-20 months	Tandu	36	16.5	0.46	Hybrid / intermediate, more reminiscent of Assamese macaque
5	5 March 2005	Tawang Khartoot (near Bomdir), 2300 m	Female ~1.5 years	Rani	34.5	14.2	0.41	Hybrid / intermediate, more reminiscent of Arunachal macaque

No.	Date	Location, site of capture & altitude	Sex & age	Name	Head-body length (cm)	Tail length (cm)	Tail to head-body length ratio	Species identity
6	23 April 2005	Tawang Bomleng (near Bhutan border), on the Tawang Chu	Female ~2 years	Tondu	33.6	13.3	0.40	Hybrid / intermediate, with traits of both species
7	23 April 2005	Tawang Below Lambardung, on the Tawang Chu	Female ~5 years	Dandu	53.7	21.0	0.39	Assamese macaque (?), with faint temple stripes
8	25 April 2006	Lumla	Female Juvenile	Rani	34.5	13.3	0.39	Hybrid / intermediate between the two species
9	27 April 2006	Zemithang	Female Infant		31.2	11.3	0.36	Arunachal macaque
10	30 April 2006	Sejusa+Tipi	Male Adult		61.0	29.0	0.48	Assamese macaque (?)

APPENDIX 3. FOOD PLANTS OF THE ARUNACHAL MACAQUE IN TAWANG DISTRICT, ARUNACHAL PRADESH

The information on many of the food plants was obtained from direct observations and for a few species, from an examination of macaque faeces.

1. *Erythrina arborescens* – Locally known as *nyang sheng*, this deciduous small tree or shrub was found throughout the district up to 3000 m, largely dominating the secondary vegetation. Macaques were observed to feed on all parts of this species, including young leaves, leaf stalks, young shoots, inner bark, flowers and pods. This species formed one of the major food plants of the Arunachal macaque.

2. *Elaeagnus parvifolia* – Locally called *tham raep*, this deciduous shrub grows to a height of about 2 m and was found extensively in secondary vegetation. Macaques were observed to consume the small red fruits of this shrub, spitting out the seeds after mastication. The fruiting season of this shrub in the study area was during the months of June to August.

3. *Elaeagnus pyriformis* – Locally known as *gyam raep*, this deciduous climber, growing to a height of more than 2 m, was found in only in a few restricted sites in the study area. The local people reported that the macaques fed on the red fruits of the species.

4. *Rubus ellipticus* – Locally called *khom raep*, this evergreen shrub with extensive bristles and recurved spines was found in many parts of the study area but mainly in secondary vegetation. The macaques fed on the yellow berries of the species.

5. *Coriaria napalensis* – Local name not known, this is a large shrub found extensively over the study area. The macaques were observed to feed on the new leaves and black fruits of this species during April to May.

6. *Viburnum sp.* – Locally known as *pokh sheng*, this is a large deciduous shrub with red fleshy fruits; the species is not known. This plant was found throughout the study area and the macaques often observed to consume the fruits

during June to August.

7. ***Fragaria nubicola*** – Locally known as *sam raep*, this is a wild strawberry and was found commonly throughout the study area. The macaques were occasionally observed to distribute themselves on the grassy slopes where the plants grew extensively and forage on them.

8. ***Selinum tenuifolium*** – Locally called *shingroo*, this perennial was found abundantly in the study area. The macaques fed on the whole plant. The local people too occasionally use this plant as a part of their diet.

9. ***Magnolia campbelli*** – Locally known as *nungong sheng*, this large deciduous tree was found singly and relatively rarely in some parts of the study area above 2500 m. The macaques were observed to consume the large white flowers of this tree during February to April. It is noteworthy that they fed exclusively on the basal part of the petals, while the rest of the flower was discarded. On closer examination of the fallen flowers of this tree in Zemithang, we found feeding signs of the barking deer *Muntiacus muntjac*; deer pellets were also seen below the tree.

10. ***Salix sikkimensis* or *daltoniana*** – Locally called *gleng sheng*, this is a deciduous small tree or shrub found throughout the Tawang district; the species, however, is not clearly known. The macaques were observed to feed on the catkins of this plant during February to March. They ingested the entire inflorescence but spat it out after mastication. The catkins, which had mild sugary nectar, were also occasionally consumed by the local people.

11. ***Debregeasia longifolia*** – Known as *chipli ghaas* in Nepali, this shrub was found growing in secondary scrub vegetation throughout the district. The macaques fed on the young leaves during April to May and on its fruits during November to December.

12. ***Aconogonum molle*** – Locally known as *chamcha*, this perennial shrub grew throughout the district. The macaques were chewed on the stems, possibly for its mildly salty water content, a feature that makes this plant popular with the local people as well.

13. ***Morus acidosa*** - Local name not known, this is a small tree found occasionally in the Zemithang area. The macaques fed on the young leaves and leaf stalks during June to August.

14. ***Persicaria capitata*** – Locally called the *man choo*, this low-trailing rooting perennial was found in mainly in secondary vegetation, where the macaques

occasionally fed on its stems.

15. ***Fagopyrum dibotrys*** – Locally known as *peng them*, this is another low-trailing rooting perennial of the secondary vegetation. The macaques were occasionally observed to feed on the leaves of this plant.

16. ***Primula denticulata*** – Locally known as *shingchung minto*, this perennial was found growing in many parts of the study area. The macaques were observed to feed on its inflorescence during February to March, although the flowers or leaves were not consumed.

17. ***Prunus cerasoides*** - Locally called *krengpa sheng*, this medium-sized deciduous tree was found only rarely in the study area. The macaques consumed the leaves of this tree.

18. ***Rhododendron keycei*** - Local name not known, this uncommon species of *Rhododendron* was a small tree. The macaques fed on the pale orange flowers of this species during the month of May.

19. ***Pteridium sp.*** - Locally known as *tha*, this was a commonly found species of fern. The macaques were observed to dig up the rhizomes and feed on its inner tissues during March to April in a livestock grazing pasture at an altitude of 2700 m.

20. ***Cirsium verutum*** - Locally known as *roong zum*, this thistle was found in many parts of the study area. The macaques were observed to pick up the purple flower heads and feed on them.

21. ***Pyrus sp.*** - Locally known as *shoo tho*, this is a wild apple tree found in the forested tracts close to the river in Zemithang area. Macaque feeding signs were noticed on the apples during August.

22. ***Rhus wallichii*** – Locally known as *uru sheng*, this is a large deciduous tree with a milky juice irritating to the human skin, found in many parts of the study area. The species is not clearly known. The macaques consumed the small globular fruits during June and July. The local people claimed that they did not touch this plant as this led to a severe painful rash accompanied by high fever.

23. ***Pteracanthus urticifolius*** – Local name not known, the identity of this species needs confirmation. The macaques were seen to feed on the young leaves and shoots of the plant, a perennial distributed widely across the study area.

24. ***Glochidion sp.*** – Local name not known, this small deciduous shrub was only seen in the Zemithang area and is likely to be a parasite. The macaques

consumed the non-fleshy reddish-yellow fruits, spitting out the seeds whole, during May to June.

25. *Laportea terminalis*? – Locally called *shou zing*, this perennial with severely stinging hairs was found through out the study area where the macaques fed on its young leaves and shoots. The species, however, requires confirmation.

26. *Hedchyium sp.* – Local name not known, this unknown species of the Zingiberaceae was distributed throughout the study area. The macaques consumed the inner parts of the stem, though only occasionally, but also picked up and fed on the flowers, a dense spike.

27. Unknown wild apple tree – Locally known as *Lhasa tho* or *Shar tho*, this large shrub with big spines appeared to be a wild apple tree and was cultivated in a few villages in the study area. The macaques were reported to feed on the apples by the local people and we too observed feeding signs on them. Some of the local people reported using the juice of this fruit, together with vegetable colors, in the dyeing of fabrics.

28. Unknown herbaceous plant – Locally known as *thabarang man*, this perennial plant is characterised by linear leaves longer than the stem, a 3-5 cm-long inflorescence with 1-2 white flowers, and star-like flowers with lanceolate petals. This plant was found in many parts of the Zemithang area and the macaques were observed to feed on the whole plant. The local people also reported eating it and occasionally cultivated a particular variety of this species.

29. Mushroom sp. – Local name not known, this unknown species of mushroom with a flat head pale brown in color was found close to a stream in an oak forest, at an altitude of c. 2300 m. The macaques were observed to consume the head of the mushroom while the rest was left untouched.

30. *Arundinaria sp.* - Locally called *saa*, this unknown high-altitude species of bamboo was found to form the undergrowth in a fir *Abies densa* forest at an altitude of about 3300 m. The macaques fed on the young leaves of the species.

Apart from these above-mentioned species, the Arunachal macaque fed on eight other plants that could not be identified. The troops also raided orchards for apples and plums and entered agricultural fields to feed on virtually anything that was grown there; these included millet, maize, wheat, buckwheat, chillies, potatoes and other vegetable crops.

Macaca munzala*: A New Species from Western Arunachal Pradesh, Northeastern India

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Macaca, comprising 20 well-characterized species, represents the largest and one of the most ecologically and socially diverse of all the nonhuman primate genera. We report the discovery of a macaque that is new to science from the high altitudes of western Arunachal Pradesh, a biodiversity-rich state in northeastern India. We propose the scientific name *Macaca munzala* and the vernacular name *Arunachal macaque* for the species. It shares morphological characteristics independently with the Assamese macaque (*Macaca assamensis*) and with the Tibetan macaque *M. thibetana*; like them, it appears to belong to the *sinica* species-group of the genus. However, the species is distinctive in relative tail length, which is intermediate between those of Tibetan and Western Assamese macaques, the subspecies with which it is sympatric. It is also unique in its altitudinal distribution, occurring largely at altitudes between 2000 and 3500 m. We provide a morphological characterization of the species, report preliminary data on its field biology and discuss possible taxonomic identity in relation to the other closely-related species of *Macaca*.

KEY WORDS: Arunachal macaque; *Macaca munzala*; *Macaca assamensis*; *Macaca thibetana*; *sinica* species-group; Arunachal Pradesh; India.

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INTRODUCTION

The northeastern Indian state of Arunachal Pradesh ($26^{\circ}28'-29^{\circ}30'N$ and $91^{\circ}30'-97^{\circ}30'E$; $83,743 \text{ km}^2$) is uniquely located at the junction of the Eastern Himalaya and Indo-Burma, a region that is among the world's 25 global biodiversity hotspots. The state is home to a diverse array of large mammals including primates. Wildlife research and exploration in Arunachal Pradesh has so far largely remained restricted to low and mid-elevation habitats, with high altitude ($>3000 \text{ m}$) wildlife being virtually unexplored and unprotected. It was, therefore, not entirely surprising when 2 expeditions (August-September 2003 and April-May 2004) to inventory the high altitude wildlife of Arunachal Pradesh led to the discovery of a fairly large population of an undescribed macaque (*Macaca*) in the state's westernmost districts of Tawang and West Kameng (Fig. 1; Mishra *et al.*, 2004; Sinha, 2004). We observed 14 multimale, multifemale troops of this largely terrestrial primate—the Arunachal macaque (earlier referred to as the Tawang macaque; Sinha *et al.*, 2004)—in different habitats over an area of *ca.* 1200 km^2 (Table I). We propose the scientific name *Macaca munzala* for the species,

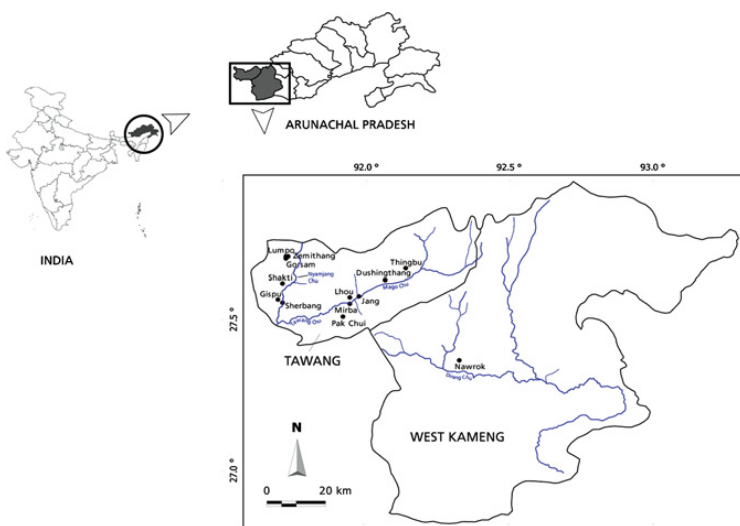


Fig. 1. Map of Tawang and West Kameng Districts, Arunachal Pradesh, showing sighting locations of *Macaca munzala*.

Table 1. Sightings of *Macaca munzala* in Tawang and West Kameng Districts, western Arunachal Pradesh

Serial Number	Locality	Date	Troop Size	Substrate	Habitat
1	Gaspu, Lower Nyamjang Chu Valley	19 August 2003	>4	On the ground	2230 m, roadside in degraded broadleaved forest, close to an isolated crop field
2	Zemithang, Upper Nyamjang Chu Valley	20 August 2003, 29 April 2004	>6, 17, with 6 infants	On the ground	2180 m, roadside in degraded broadleaved forest, close to crop fields
3	Gorsam	21 August 2003	>18, with 2 infants	On trees, at a height of 15–20 m	2030 m, early in the morning, roosting in the canopy of a riverine forest
4	Mirba, Mukto	27 August 2003	5	On the ground	2620 m, roof of an abandoned hut in a crop field
5	Pak Chui, Mukto	28 August 2003	>7	On the ground	2670 m, undisturbed oak forest; heard vocalizing
6	Jang	1 September 2003	>5	On the ground	2120 m, roadside in degraded open scrub forest
7	Jang	23 September 2003	>4	On the ground	2470 m, broadleaved forest
8	Dushingthang	23 September 2003	>8	In the canopy, at a height of 15 m	2700 m, broadleaved forests by a steep cliff
9	Nawrok, Lower Namshu Valley	26 April 2004	>17	On the ground	2870 m, sloping grassland by a broadleaved forest
10	Lhou	27 April 2004	34, with 5 infants	On a rocky outcrop	2100 m, roadside in degraded open scrub forest
11	Lumpo, Upper Nyamjang Chu Valley	29 April 2004	>16, with 5 infants	On a rocky outcrop	2180 m, degraded broadleaved forest
12	Shakti, Upper Nyamjang Chu Valley	29 April 2004	>8	On the ground	1650 m, roadside in degraded broadleaved forest
13	Sherbang, Lower Rong Chu Valley	5 May 2004	>6	On the ground	2100 m, roadside adjacent to broadleaved forests
14	Thingbu	9 May 2004	>9	On the ground	3000 m, undisturbed conifer forest

and provide an account of its morphology with some observations on its field biology.

Although the elevation in Tawang and West Kameng Districts generally ranges between 1000 and >6000 m and we surveyed much of this gradient, the macaques were generally encountered at altitudes between 2000 and 3000 m (Table I). Reports from local people suggest that they occur up to 3500 m. The species thus occurs at the highest altitude reported for any macaque in the Indian subcontinent (Menon, 2003). Subtropical broadleaved forests dominate the vegetation within this elevational range, though cultivation is common in areas where the terrain is less rugged. The macaques appeared to be relatively tolerant of human presence and habitation, occasionally occurring close to villages and crop fields (Table I). They were, nevertheless, wary in the presence of people, and in most cases, moved away on being closely observed. Inside undisturbed forests, they seemed extremely shy, rapidly disappearing through the undergrowth as soon as they sensed human presence.

THE ARUNACHAL MACAQUE

Order Primates Linnaeus, 1758

Superfamily Cercopithecoidea Gray, 1821

Family Cercopithecidae Gray, 1821

Subfamily Cercopithecinae Gray, 1821

Genus *Macaca* Lacépède, 1799

Macaca munzala species novum

Holotype: An adult male, photographed by M. D. Madhusudan (Fig 2 Top panel)

Paratypes: Two adult and one subadult males, photographed by M. D. Madhusudan (Fig. 2 Bottom panel). We are trying to collect specimens of the species. These will be designated as paratypes and deposited in the State Forest Research Institute in Itanagar, Arunachal Pradesh. If live specimens are obtained, they will be maintained in an appropriate captive facility and their skins, skulls and skeletons again deposited in the State Forest Research Institute upon their demise.

Type locality: Zemithang (27°42'N, 91°43'E), Tawang District, Arunachal Pradesh; altitude 2180 m above sea level. The holotype belonged to a multimale multifemale troop of *ca.* 17 individuals, and was photographed on August 20, 2003 while he foraged in degraded broadleaved forest, close to crop fields.

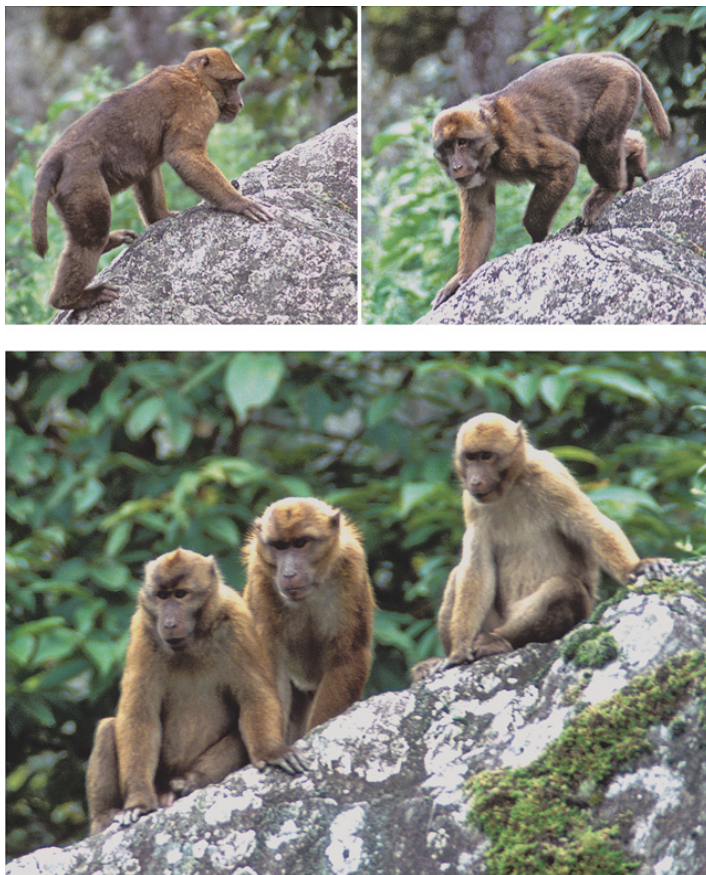


Fig. 2. *Macaca munzala*. Top panel: The adult male (left: right lateral view; right: left lateral view) is the holotype for the new species. For relative body-size measurements of adult individuals, we used profile photographs like this one. Bottom panel: The 2 adult males (left and center) and the subadult male (right) represent paratypes for the species.

Diagnosis: A species within the *sinica* species-group of *Macaca* (Fooden, 1980), as evidenced by penile morphology. The taxon can be distinguished from *Macaca sinica*, *M. radiata*, *M. assamensis pelops* and *M. thibetana* by relative tail length and external morphology and from *M. assamensis assamensis* by distinctive facial features and external morphology. More

uniquely, it can be differentiated from all the species of the *sinica* species-group by a suite of traits including a prominently dark crown patch, characteristic facial marks on the temple and forehead, pale collar of hair around the neck and distinctive relative tail length.

Description: Individuals are generally large and heavyset with a short tail (Fig. 2). The body of adults is dark brown to dark chocolate dorsally, with the upper part of the torso and the distal parts of the limbs becoming paler (ranging from light brown to olivaceous). The hands and feet are also pale brown (similar to the fore limbs), though they are relatively darker in juveniles. The ventral part of the trunk is lighter in some individuals, but similar to that of the upper torso in most individuals. The general pelage is long and dense, especially in the upper torso, while the lower torso and ventral part of the trunk have shorter, smoother hairs.

The tail is very dark, similar to the dorsal surface of the lower torso and the hind limbs. Although juveniles appear to be similar to adults in their general appearance and pelage characteristics, a striking feature common to all juveniles are their relatively hairless, whip-like tails, tapering distally to a narrow tip. The tail length of the species is distinctive, both in adults and in juveniles. The relative tail length of 2 adult males, measured (from photographs) as the ratio of the length of the tail to that of the head and body, are 0.39 and 0.45 (Table II, Fig. 2), while that of 3 captive juveniles (measured directly) are 0.36, 0.39 and 0.40.

The front of the crown of every individual is very characteristic in having a prominent pale-yellow patch with a central group of dark hairs. In one

Table II. Relative tail length measurements of Arunachal macaques, 2 subspecies of Assamese macaques and Tibetan macaques

Species and age-sex category	Measure and range	Reference
Tail length/Head and body length		
<i>Macaca munzala</i> Adult males	0.39–0.45	This study
<i>Macaca munzala</i> Juveniles	0.36–0.40	This study
<i>Macaca assamensis assamensis</i> Adult males	0.26–0.44	Fooden, 1982
<i>Macaca assamensis pelops</i> Adult males	0.50–0.69	Fooden, 1982
<i>Macaca assamensis pelops</i> Juveniles	0.40–0.69	This study
Tail length/Hindfoot length		
<i>Macaca munzala</i> Adult male, juvenile	1.52, 1.28	This study
Macaque described by Choudhury (1998) Adult males	0.80–1.20	Fooden, 2003
<i>Macaca assamensis assamensis</i> Adult males	1.11–1.56	Fooden, 2003
<i>Macaca assamensis pelops</i> Adult males	1.73–2.07	Fooden, 2003
<i>Macaca thibetana</i> Adult males	0.33–0.54	Fooden, 2003

adult male, it formed an erect tuft, though in every other individual it was more reminiscent of a whorl of hairs. Surprisingly, when we surveyed them during the second expedition, in early summer, the dark patch was present but the pale yellow patch was not as distinct, which raises the possibility that the species may exhibit minor seasonal variation in coat color.

The head is very prognathous with the upper part of the face significantly broader than the muzzle, especially in adult males. The facial skin is generally dark brown (darker than that of the body in several of the adult males). There is a prominent dark patch on either temple, occasionally extending as a stripe from the outer corner of the eye or the upper cheek to the ear. We observed this feature in virtually every individual, and it appears to be a distinctive species-specific morphological trait. Many individuals also have a long, thin, dark stripe that runs along the lower forehead above the eyes, a feature relatively more prominent in juveniles. The skin around the eyes is usually pale in some individuals, producing a faintly spectacled appearance.

The nose is relatively flaring and occasionally lighter in color, particularly in adults. In contrast to Tibetan macaques, side-whiskers and beard are not prominently developed and the dark ears are, therefore, often clearly visible in anterior view. In several adult males and females there is also a dorsal ring of lighter-colored hair between the head and trunk, which distinctly appears as a pale collar even when viewed from afar.

The glans penis, on superficial examination, is distinctive in being prominently inflected relative to the shaft of the penis, broad with an acute apex, and sagittate in dorsal view. The dark pink glans has a prominently thickened corona and a subterminal urethral meatus that is dorsoventrally oriented.

Distribution: We list the locations where the taxon has been sighted in Table I. The species is distributed over much of Tawang District and in the western part of West Kameng District of Arunachal Pradesh. They may also occur in other parts of Arunachal Pradesh, and in adjoining areas of Bhutan and Tibet.

Etymology: The proposed specific name for the taxon is derived from its local name in Dirang Monpa: *mun zala*, literally meaning deep forest (*mun*) monkey (*zala*). The dialect is spoken by the Monpa, an important Buddhist tribe of West Kameng and Tawang Districts of Arunachal Pradesh.

TAXONOMIC IDENTITY

Although reminiscent of Assamese macaques in general physiognomy, Arunachal macaques are strikingly different from either *Macaca*



Fig. 3. *Macaca assamensis pelops*, which is sympatric with *M. munzala*. This adult male was photographed at Kurseong (altitude 1480 m) in West Bengal, eastern India.

assamensis pelops (Figure 3) or *M. a. assamensis* (Fooden, 1982) in their extremely dark coat color, hirsute underside of the body, relatively stocky tail, dark brown facial skin, distinctive facial marks on the temples and forehead, and lack of prominent chin and cheek whiskers (Fig. 2 vs. 3). Further, all Arunachal macaques have a prominent dark patch on the crown, while most Assamese macaques have a smooth hair arrangement on a pale crown (with an occasional central parting), though rare individuals may have a whorl or tuft of hair there (Fooden, 1982; Sinha, *pers. obs.*).

The 2 subspecies of the Assamese macaque apparently have disjunct geographical distributions, though their exact limits are unknown (Fig. 4;

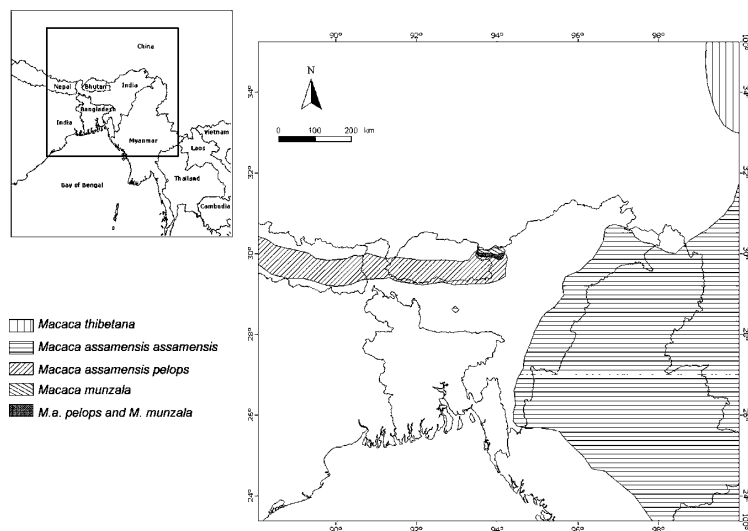


Fig. 4. Map of India and adjoining countries in southeastern Asia showing the partial distributions of *Macaca assamensis pelops*, *M. a. assamensis* and *M. thibetana* (adapted from Fooden, 1982 and Sinha, *unpubl.*) relative to that of *M. munzala*. Although *Macaca assamensis pelops* and the *M. munzala* are sympatric, they have nonoverlapping altitudinal distributions. The eastern limit of *Macaca assamensis pelops*, the western limit of *M. a. assamensis*, and both the eastern and western limits of *M. munzala* are unknown.

Fooden, 1982; Brandon-Jones *et al.*, 2004; Sinha, *unpubl.*). Western Assamese macaques (*Macaca assamensis pelops*) occur from central Nepal eastward through the Indian states of Sikkim and northern West Bengal to western Arunachal Pradesh. *Macaca assamensis assamensis*, the eastern subspecies, ranges from the Indian states of eastern Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram eastward through northern and eastern Burma to Thailand, Laos, Vietnam and the Chinese provinces of Yunnan and Guangxi, though Jiang *et al.* (1993) suggest that they may be heterogeneous, divisible into 2 or 3 subspecies. Morphologically, the 2 Assamese macaque subspecies can only be distinguished from each other by relative tail length (Table II; Fooden, 1982).

Surprisingly, the relative tail lengths of Arunachal macaque males overlaps those of Eastern Assamese macaques (Table II) though, in its distribution, it is sympatric only with the Western Assamese macaque, the adult males of which have significantly longer relative tail lengths (Table II; see Fig. 3). This is also true of juveniles of the species; in contrast to the

relative tail length of the Arunachal macaque that range from 0.36 to 0.40, the relative tail lengths of 2 captive Western Assamese macaque juveniles that we measured are 0.49 and 0.63 (Table II). While relative tail length of *Macaca assamensis* varies by age and sex differently in its 2 subspecies (Fooden, 1982), our preliminary evidence indicates that there may be similar age differences in the relative tail length of the Arunachal macaques.

Another index of relative tail length that Fooden (2003) has used recently primarily due to the absence of reliable data on head and body length is the ratio of tail length to that of the pes. There is a clear progressive decline in the ratio in adult males across species of the *sinica* species-group: from a mean of 1.86 in *Macaca assamensis pelops* to 1.26 in *M. a. assamensis* and 0.41 in *M. thibetana* (Fooden, 2003; Table II). A photographic analysis post hoc of the ratio for an adult male and a juvenile Arunachal macaque indicates once again that they are relatively closer in morphometric ratios to Eastern Assamese macaques rather than to the Western Assamese macaques, with which they are sympatric.

With rare exceptions, both Assamese macaque subspecies are restricted to a relatively narrow altitudinal zone between 150 and 2000 m over their entire distributional ranges (Fooden, 1982; Sinha, *unpubl.*). The significant morphological differences between Arunachal macaques and the 2 Assamese macaque subspecies (which are otherwise remarkably similar to each other) as well as the altitudinal specificity of their respective distributions thus make it highly improbable that Arunachal macaques are a subspecies of *Macaca assamensis*.

Arunachal macaques strikingly resemble Tibetan macaques (*Macaca thibetana*) in having dark, long pelage, dark facial skin, and the almost ubiquitous dark patches (or occasionally, stripes) on the crown and the temples (Li, 1999). Tibetan macaques are distributed principally in east-central China, at similar altitudes of 1000–2500 m, but *ca.* 1000 km away (calculated from Fooden, 1986; Fig. 4). Most importantly, Arunachal macaques differ from the much heavier, stockier and more hirsute Tibetan macaques in having a prognathous head and a prominent tail, which is virtually absent in the latter (Table II). They also lack the prominent bushy pale buff-colored beard and full cheek whiskers characteristic of Tibetan macaques.

In conclusion, Arunachal macaques display unique morphological features, consistently shared by all individuals in a population spread over 1200 km², and an unusual altitudinal distribution not exhibited by any other macaques in the area. Their distinctive penile morphology, characteristic of the *sinica*-group of *Macaca* (Fooden, 1980), together with a suite of morphological traits shared independently with the Assamese macaque and the Tibetan macaque clearly indicates that they are a new species within the *sinica* species-group with possibly strong evolutionary connections to both Assamese and Tibetan macaques.

Choudhury (1998, 2000, 2002) described a troop of macaques from an altitudinal range similar to that of the Arunachal macaque in the Eagle's Nest Wildlife Sanctuary of West Kameng District. He provisionally identified them to be Tibetan macaques or a subspecies of Assamese macaques on the basis of their relatively short tails, more prominent buffy side-whiskers, and differences in their vocalizations. Subsequently, Fooden (2003) calculated the tail-to-pes of 2 individuals from sketches made by Choudhury and suggested that the population may actually represent the *Macaca assamensis assamensis*. The new species that we report here have relative tail lengths significantly larger than the macaques sighted by Choudhury, and they also lack the buffy side-whiskers. They also differ significantly from Assamese macaques in having dark pelage and facial skin, stocky tail (which is relatively hairless in juveniles) and distinctive facial markings. Choudhury's (1998) incomplete description could well apply to the Arunachal macaque, which has a notably dark pelage and facial skin and a dark crown patch, that were not mentioned by Choudhury. A comparative analysis of our photographs with the solitary one of Choudhury (1998), failed to resolve the issue primarily due to a lack of clarity in his photograph.

Among extant primates, *Macaca* with 20 well-characterized species (Brandon-Jones *et al.*, 2004) occupies a geographical range that is only smaller than that of *Homo*. In terms of wide distribution, numerous populations and range of habitat types exploited, macaques have thus achieved outstanding evolutionary success. Although their distribution and numbers have reduced drastically since the Pleistocene, when macaques reached the pinnacle of their evolution, the ecological adaptability and behavioral flexibility of the genus has undoubtedly contributed to their colonizing success and the ability of some species to thrive in habitats undergoing drastic human modification (Lindburg, 1980; Fa and Lindburg, 1996). Accordingly, the discovery of the Arunachal macaque and our continuing work on the behavioral ecology and population genetics of the species should significantly contribute to the growing understanding of their evolutionary ecology.

CONSERVATION STATUS

During our surveys, local people reported that the macaques frequently damage crops and are sometimes killed in retaliation. The people of Tawang and the high altitudes of West Kameng belong predominantly to the Buddhist *Monpa* tribe and, in general, do not eat primates. However, some hunting of primates for meat is reportedly carried out by government employees from other Arunachali tribes stationed there.

The intensive survey currently being conducted in the Tawang and West Kameng Districts of Arunachal Pradesh should enable us to more closely examine the survival threats confronting this species and, if necessary, consider their inclusion in the IUCN's Red List of Threatened Species (IUCN, 2000) and the Indian Wildlife (Protection) Act of 1972 (Anon, 2003). Establishment of community awareness and conservation programs and designation of a protected area that is locally appropriate (such as a conservation or community reserve) may also be urgently required to safeguard the future of this enigmatic species alongside that of the fascinating, but threatened, wildlife assemblage of western Arunachal Pradesh.

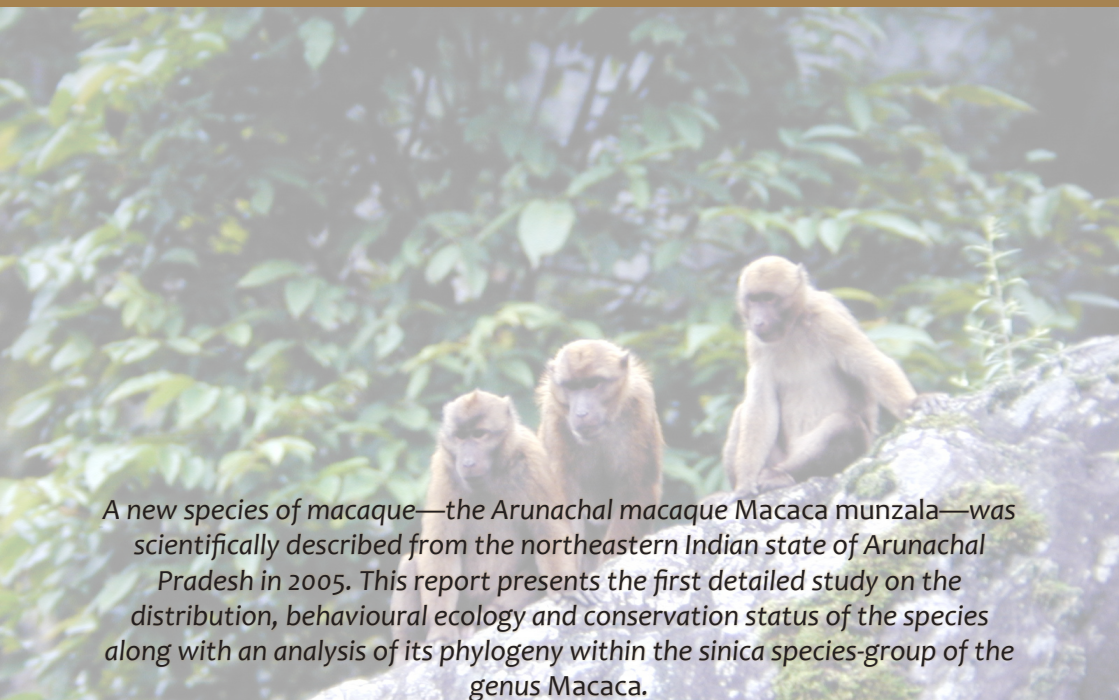
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A photograph of three Arunachal macaques (Macaca munzala) sitting on a large, mossy rock in a lush, green forest. The macaques have light brown fur and are looking towards the camera. The background is filled with dense foliage and trees.

A new species of macaque—the Arunachal macaque *Macaca munzala*—was scientifically described from the northeastern Indian state of Arunachal Pradesh in 2005. This report presents the first detailed study on the distribution, behavioural ecology and conservation status of the species along with an analysis of its phylogeny within the *sinica* species-group of the genus *Macaca*.